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THE

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MILK RECORDING

Information accumulated by Official Milk Recording Schemes has, in many countries and in a comparatively few years, been utilized to a considerable extent by those responsible for promoting increased and economic milk production. More important still, the information is likely to prove of even greater value in future breeding programmes and in efforts to reorganize farming methods so as to reduce the costs of milk production. Milk recording has, in fact, proved its usefulness not only in the older and more developed agricultural conditions of Europe, but also in the more recent, but rapidly developing, countries and it is highly desirable that in a young Colony, such as Kenya, every encouragement and support should be given to the local recording schemes. In order to help stimulate interest in milk recording locally, to publicize the information from local herds and to make the data available to geneticists here and overseas, summaries of the records from leading local cows are being published in this JOURNAL.

Although milk recording was practised privately by a number of individual, but far-seeing, farmers in several European countries in the second half of the nineteenth century, the first official scheme originated in Denmark. From 1891 several groups of Danish farmers associated with creamery development began to pool their individual records and, in 1895, these groups amalgamated into the Recording Society which set the pattern for subsequent development. During the first part of this century, more and more recording societies were established in Denmark and all were mutually associated under common rules which governed the type of records to be kept, their methods of collection, the means for checking, supervising and collating the records, and the issue of certificates of yield and merit. Even in its early days, the Danish system went further than many systems in operation to-day in other countries. Not only was the weight of milk in each year recorded (irrespective of the number of days dry), but data on butterfat contents and yields were regularly reported together with information on food consumption per cow, details of returning cows and aborters. Where the Danish records excelled, even in the early days, was in the relationship drawn between yield and food requirements. A high yield by itself, although most desirable, is of less value than a high yield per unit of food consumed. It is well known that certain individual cows make more efficient use of a given quantity of food and, in the interests of economic production, it is a better policy to breed from such efficient families than from equally high-yielding animals, but which are either less efficient converters of a given ration into milk or require a high level of expensive concentrate feeding.

The material compiled by the Danish recording societies has been extensively used for the more economical rationing of individual cows, according to their level of productivity, and for facilitating the selection of desirable bulls, on the basis of the milk yields of their daughters, for use by individual farmers and for the artificial insemination centres. By 1951, 53.4 per cent of all dairy cows were being recorded in Denmark. During the same period the average milk production in all herds had risen from about 3,000 kg. (6,600 lb.) to nearly 4,000 kg. (8,800 lb.) per year, whilst the butterfat content was raised from 3.40 to 4.18 per cent. As a further example of the benefits to be derived from the information available from milk recording, the average yield, in 1951, for recorded herds was 600–700 kg. (1,320–1,540 lb.) higher than the average of all herds and not just of those which were not recorded.

Developments in other countries have been somewhat similar, although the rates of development, the details recorded and the methods of recording have varied with the conditions and the support given by local farmers. Without going into the historical development in all countries, it may perhaps be useful to refer to the events in the United Kingdom as a means of indicating the growth of the movement amongst, at first, unresponsive farmers and how the latter were converted by the recording system from traditional views on breeding to practices in line with modern genetic opinions.

Throughout the greater part of the nineteenth century there was no great market for milk in the United Kingdom and, with the successful development of distinctive types of beef animal coupled with the overseas demand for pedigree beef bulls, there was little need for specialized dairy breeds. Concentration on pedigrees, rather than the actual merit of the individual animals developed during the changing farming conditions, prior to the disastrous year of 1879, and this concern with ancestral instead of progeny performance, was to influence British farming policy until well into the twentieth century. It was also responsible for the reluctance of breeders to cull inferior animals which, on their pedigrees, were eligible for entry in Herd Books. During the second half of the last century, the Breed Societies began to dominate breeding programmes and one of their first actions was to establish standards of excellence for each breed. Attention was focused, particularly by the importance of show-ring successes, on high condition and conformational characters which, at the time, were believed to be correlated with efficiency and usefulness as dairy animals. Since judgment and selection of dairy stock on such lines was not founded on reliable data, it is not surprising that the information, from the later milk recording schemes, has discredited these beliefs. What is surprising, however, is that some of these unjustified theories should have persisted in some quarters to the present day.

From 1880, the rising costs of producing British beef, together with the competition developing from overseas supplies of meat, induced many farmers to turn more towards milk production, especially since improvements in the handling of milk and the greater facilities for transport by rail, opened up expanding urban milk markets which, previously, had been too remote from many farms. Increasing attention was then directed to milk yields, and the British Dairy Farmers' Association instituted milking trials at their show in 1879 and this example was followed by the Royal Agricultural Society in 1885. Prior to this, all milking classes at the Royal Show (since 1859) had been judged by inspection only and the introduction of milking trials influenced the farming community very slowly, as may be gathered from the fact that, in 1899, the Shorthorn Society began offering prizes for pedigree cows which, by inspection, were considered to possess dairy qualities.

During the period 1880–1910, increasing attention was paid to the recording of milk yields by progressive farmers and, from 1882, occasional references were made, in the agricultural literature, to the values to be derived from individual milk records in the selection and breeding of dairy stock. Certain of the dairy breed societies and public bodies interested in agricultural education promoted milk recording amongst groups of farmers, but official recording schemes were not started until 1905 in Scotland, nor until 1914 in England.

However, milk recording did not find favour with the majority of farmers and the National Scheme was largely replaced by schemes, fostered by the breed societies, which tended to be restricted to a limited circle of pedigree breeders. During the period between the two World Wars, many attempts were made to encourage farmers to support milk recording by establishing, within the various Herd Books, superior merit classes, such as "Dams Qualified for Bull Breeding", "Register of Merit for Sires", etc. The qualifying conditions were based on either a single lactation yield or on the average yield of a number of selected daughters and, generally, were too lenient to effect any significant improvement in the milk productivity of the breed. On the other hand these steps, when they were introduced, were in advance of average farming thought and undoubtedly served a most useful purpose in inducing more breeders to record milk yields than would otherwise have been the case, and also focused attention on the need for progeny records in selecting bulls instead of reliance on "paper pedigrees". It is easy to be wise after the event and to criticize these early British efforts in the light of the spectacular advances in countries such as Denmark, U.S.A. and New Zealand, but the real defect of the British schemes has been a lack of elasticity and a failure to allow for rapid changes in the light of advancing knowledge and the extension of agricultural education.

The greatest advance yet achieved in British milk recording followed the establishment of the Milk Marketing Board in 1933, and its concern with efficient and economical milk production which led to it assuming responsibility for milk recording in 1943. The Board realized that if economical production was to be increased rapidly, greater attention should be paid to performance records, especially in those herds which provided the industry with

bulls. In commercial herds far too little attention was directed to choosing a suitable bull which, in many cases, was regarded merely as a means of getting existing cows in milk again, with no thought for the future of the herd. The success of the Milk Marketing Board's efforts may be gauged from the fact that when it took over responsibility for official recording, 29 years after the inception of the scheme, only 5 per cent of U.K. cows were being recorded yet, within the next eight years the percentage had increased to over 20 per cent.

The advantages of milk recording for an individual farmer are to enable him to know which are his best cows, as well as those which are below average, for his herd or for his breed, and should be culled or not used for breeding purposes. By knowing the butterfat contents of the milk, the farmer is enabled to know which animals are the most productive if he wishes to sell butterfat. By knowing the yields and quality of milk from each cow, it is easy for farmers to adjust the food intake according to the total output of each animal and thereby reduce expenditure on expensive purchased concentrates. Regular recording provides an additional check on the health of the animals, on the efficiency of the labour, on the losses of milk and also on the use of feeding stuffs.

Official recording and the issuing of record certificates, both of which imply a minimum number of surprise checks, gives authenticity to the records and inspires confidence in buyers. The publishing of records by an official body advertises the superiority of herds and individual cows, whilst the sorting of official records permits an outside evaluation of the progeny records of sires and the selection of an "elite" group, based on the productivity of their offspring, from which breeders may draw the best possible bulls and the breed derive the greatest possible future benefit. Experience elsewhere has shown that the best way to improve a breed is to mate above-average females to bulls which have proved themselves capable of producing good female progeny. To prove the superiority of a bull takes time and many bulls are aged before their excellence has been proved and their period of usefulness is then limited. The next thing to using a "proved-good" bull is to use a son of his on a family of cows with a sound line of female ancestors. Such a system of genetic improvement of a herd or breed is obviously impossible in the absence of milk records.

A number of records refer only to the yield and it is frequently forgotten that real merit may be overlooked by the concentration on a single factor. Whilst total yield is a most important factor in economic production for the liquid milk trade, it does not always follow that the highest yielder produces the most butterfat for a butter market. Consequently, butterfat percentages should be recorded as well as yields and the production of butterfat should be calculated. During the last 25 years, it has been realized, in certain countries, that milk quality, as measured by the contents of fat and solids-not-fat, has deteriorated to the point where many individual milks fall below the presumptive legal minima. It is generally believed that part, at least, of this drop in quality has arisen because of the tendency to choose bulls from the highest-yielding cows, which are often below the breed average for milk quality. By selecting, for future breeding stock, the sons and daughters of a sire which has proved his ability to transmit high yields of good-quality milk, the risk is reduced. In this connexion, whilst high butterfat content is usually associated with high solids-not-fat in the milk, this relationship does not always hold and it would therefore be wise after having selected a sire, on the basis of yield and butterfat, to check the solids-not-fat content of the milk from his progeny.

To quote one excellent lactation record from a given cow is no guarantee that she is above the average of her herd or breed. It is necessary to take all her lactation records into account, as well as the interval during which the lactations have been recorded. In Kenya, the milk recording scheme follows the lead of the United Kingdom in basing each lactation record on the yield during the first 305 days after calving. Even this, however, is not sufficient for a true appraisal of a cow's worth. It is also necessary to know the "calving index", which is the interval, in days, between the last two calvings. The average index measures the extent to which the herd or cow under reference has calved at yearly or greater intervals and the Milk Marketing Board has suggested that no cow should be included in its official records if she has an index of more than 430 days. Certainly, calving index should always be included in records of performance in order that a proper reduction of the credit, for a high lactation record, may be made in

the case of cows or herds which have not bred regularly—either intentionally or accidentally.

To illustrate the effect of the above on the interpretation of lactation records, the following figures are quoted from two herd averages published in the report of the Milk Marketing Board for 1946/47:—

The first herd averaged 12,557 lb. milk for 22 lactations with a calving index of 487 days.

The second herd averaged 12,074 lb. of milk for 23 lactations with a calving index of 369 days,

and there can be little doubt about the superiority of the performance of the second herd.

The foregoing remarks set out to emphasize the benefits of milk recording and of the difficulties which have to be overcome. They are not meant to be in any way critical of the present stage of the Kenya scheme, which this JOURNAL is only too anxious to help and advertise, nor of the hard workers who have been responsible for initiating and developing it and to whom the Kenya dairy industry owes an immense debt of gratitude.

M.H.F.

CORRIGENDUM

NOTES ON OEMIDA GAHANI DISTANT (CERAMBYCIDÆ)

In the April, 1953, issue, page 180, at foot of left-hand column, the last two sentences should read:—

"For example, in April, 1951, with a rainfall of over 20 inches, the emergence was 170; in April, 1952, rainfall 12.8 inches, emergence 112. Although adults appeared in the drier months during the first two years, emergence figures were only from 4 to 20 when rain was 2 inches or less."

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NOTES ON ANIMAL DISEASES

XXV—COMMON TICKS OF LIVESTOCK IN KENYA

By A. J. Wiley, Veterinary Research Laboratory, Kabete, Kenya

(*Received for publication on 11th May, 1953*)

Of all the external parasites of livestock with which we are plagued in this Colony, ticks are, without any doubt, the most abundant and the most important. The annual loss due not only to actual deaths from tick-borne disease, but also indirectly to the necessity of tick control by dipping, must run into tens of thousands of pounds. Ticks do not, of course, confine their attacks to domestic livestock. Wild animals from the smallest rodents to the largest elephants are subject to infestation by these pests. Bats and birds and even snakes, lizards and tortoises are liable to harbour them.

Few people realize how remarkably resistant a tick is to the ravages of climate and time. They can withstand the desiccating desert conditions of the Northern Province and the cold frosty nights of the higher mountain slopes—*Rhipicephalus simus* (the black-pitted tick) has been collected at El Wak in the northern deserts and also at 11,000 ft. on the slopes of Mt. Kilimanjaro. Some years ago at Kabete a tick (*Hyalomma* sp.) was kept alive in a small glass tube for three years. During the whole of this period it had no food or attention other than occasional drops of moisture in the form of weak saline.

Classification

Before discussing individual species a few brief notes on the classification and life history of ticks will not be out of place. Ticks belong to the class *Arachnoidea*; they are not, therefore, in the strict sense of the word "insects". They are in fact more closely related to the spiders, scorpions and mites than to any of the *insecta*. There are two different families of ticks and both are represented in Kenya. These are the *Ixodidae* (hard ticks) and the *Argasidae* (soft ticks). The majority of the ticks in this Colony, however, fall into the former category. These are characterized by their hard, shiny dorsal shield and the head protruding forward in front of the body. The soft ticks lack any dorsal shield, having instead merely a leathery-like skin: their heads are hidden beneath their bodies.

Only one species of tick dealt with below belongs to the Argasid family; this is *Argas persicus* (the fowl tampan), an increasingly common parasite which inhabits chicken houses in this country.

Identification of the Hard Ticks

The more important features commonly used for distinguishing the different varieties of ticks are: firstly, the shape of the lateral margins bordering the hind part of the head is of special significance; secondly the punctations on the shield vary in density and distribution; thirdly, the presence or absence of eyes (these, when present, are situated in the hard ticks, about a quarter of the way back on each side of the dorsal shield); lastly, coloration and banding of the legs are obviously features of importance.

The sexes of the hard ticks can always be distinguished by examining the dorsal surface; in the male the hard shield extends over the entire upper side of the tick, whereas in the female it extends only over the anterior half of the body. The hind part of the female tick not covered by the shield is the portion which swells up as the creature engorges itself with blood. The male, on feeding, only swells slightly; it is the female which becomes the large, swollen creature we all know so well in East Africa.

The nymph is very like an adult female in general appearance, having only the front half of the body covered by the shield; it is, however, much smaller in size and appears more fragile. The larva, or "pepper-tick" as it is sometimes called, is no bigger than a pin-head; it has only three pairs of legs instead of the four pairs of the nymph and adult.

Life Cycle

Very briefly the life cycle of the majority of the hard ticks is as follows. The female lays her eggs, probably a few thousand. She will choose some secluded spot such as a small crack in the ground or under a stone, in which to deposit the eggs. After laying she dies. The eggs take approximately a month to hatch but

this period will vary with the temperature. The young larvæ, a few days after hatching, will clamber up the grass or nearby vegetation and await the passing of a suitable host. This may not occur for two or three months but eventually, with reasonable luck, some animal will brush past and pick them up. The larvæ then attach, feed, and after a few days, drop to the ground again. Here they moult and await the arrival of another host. After feeding as nymphs they once again drop off to moult. On emerging from their nymphal skins after this final moult they are adult ticks; the sexes are now distinguishable. After finding yet another animal on which to feed, the adult tick mates, gorges itself on blood and the female then drops to the ground for the last time to lay her eggs. The cycle is complete. Such ticks are referred to as three-host ticks.

There are other species of ticks which spend the larval and nymphal instars on the one host; they then drop, moult, and spend their adult stage on another host. These are the two-host ticks.

Boophilus decoloratus (the blue tick) is an example of a one-host tick; this species finds a host as a larva and does not leave until it is an engorged adult.

Soft ticks have different life cycles.

Obviously the methods of control employed against ticks will be dependent to a certain extent upon the life cycle of the tick concerned. The blue tick, a one-host species, will spend three or four weeks on an animal, whereas the larvæ of, say, *Rhipicephalus appendiculatus* (the brown tick), a three-host tick, may be only on the beast for as little as three or four days. Careful dipping at the correct intervals to catch the species of tick concerned, together with hand-dressing, is the usual method of controlling and eradicating ticks.

In an article of this nature it would be quite impossible to deal with more than a few of the 60 species recorded and collected in this territory. The intention here is to give notes on the more common species to be found on domestic animals. Thirteen different sorts have been chosen, all of which can be considered common, at least in some parts of the country, and incidentally, all but one of which have been incriminated in the carrying of disease.

In order to keep these notes as short as possible, only the males are described in the text. As the ticks to be dealt with are all common varieties it should be possible, in most cases, to pick out a male for purposes of identification; illustrations only, then, will be given in the cases of females. Also for the sake of brevity, none of the innumerable game animals from which ticks have been collected is included in the list of hosts. Only the domestic animals are mentioned here.

Information on the control of ticks may be found in an earlier article, "Notes on Animal Diseases, II—East Coast Fever and Related Diseases" (this JOURNAL, Vol. 12, 1947, p. 167).

ARGASIDÆ—THE SOFT TICKS

Argas persicus, Oken.—The Fowl Tampan or the Fowl Tick

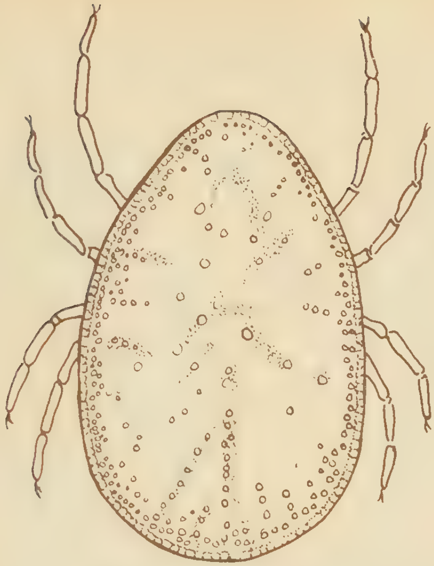
Habits.—This is essentially a parasite of fowls, as its name implies. It does occur, however, on other birds and can occasionally attack man. This tick is becoming increasingly frequent in hen-houses throughout the Colony. It is probably not indigenous to this part of the world; it is likely that, with the increasing popularity of the domestic fowl, it was imported comparatively recently.

The fowl tick, during the daytime, hides up in cracks in the perches and in the posts of the house itself. It emerges during the hours of darkness to feed on the fowls and, with the exception of the larvæ, the majority are back in their hideouts by daylight.

Life History.—Except in this instance it is not intended in these notes to give the life history of each species. However, in this case, as we are dealing with one of the soft ticks, its behaviour is quite different from those which follow.

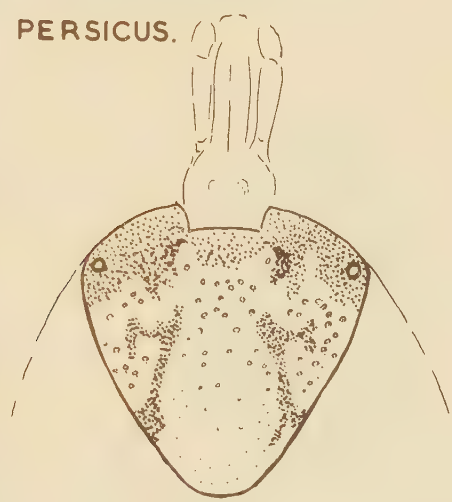
Batches of 20 to 100 eggs are laid by the female in some secluded spot. She does not necessarily die, as do the females of the hard ticks after laying. It takes the eggs about three weeks to hatch into larvæ. These then go in search of a bird and attach for perhaps a week before dropping off to moult to nymphs. Unlike the hard ticks, there are two nymphal stages with a moult between each. The adult phase follows, with occasional feeds lasting only a few hours at a time.

Disease.—The fowl tick is capable of carrying *Spirochæta anserina*, a fatal disease of poultry. It has also been shown to be a transmitter of *Aegyptionella pullorum*, a protozoon



ARGAS PERSICUS.

Male.



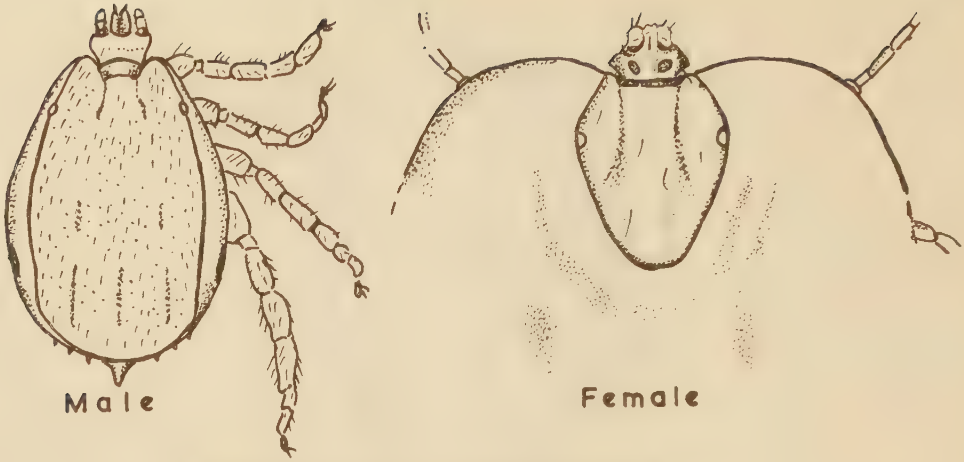
Female.

AMBLYOMMA GEMMA.

Male.

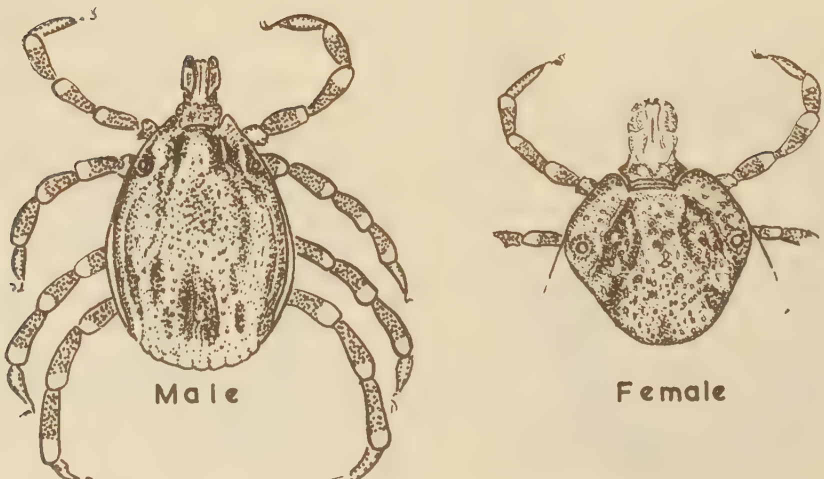
Female.

AMBLYOMMA VARIEGATUM.

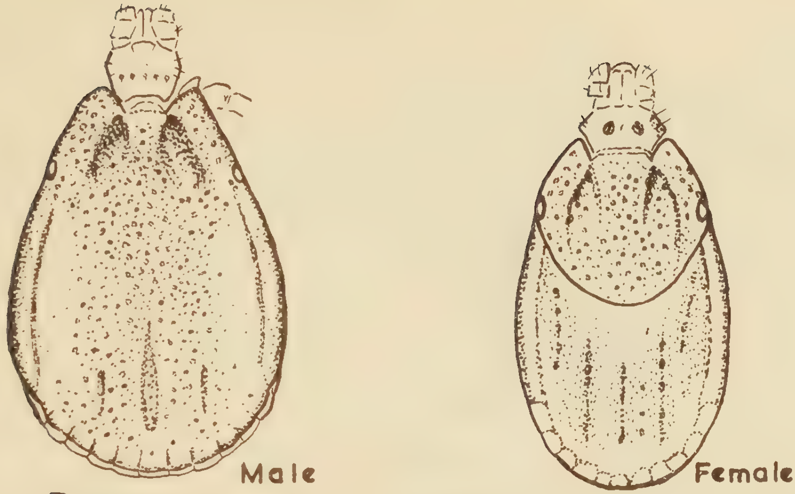


BOOPHILUS DECOLORATUS.

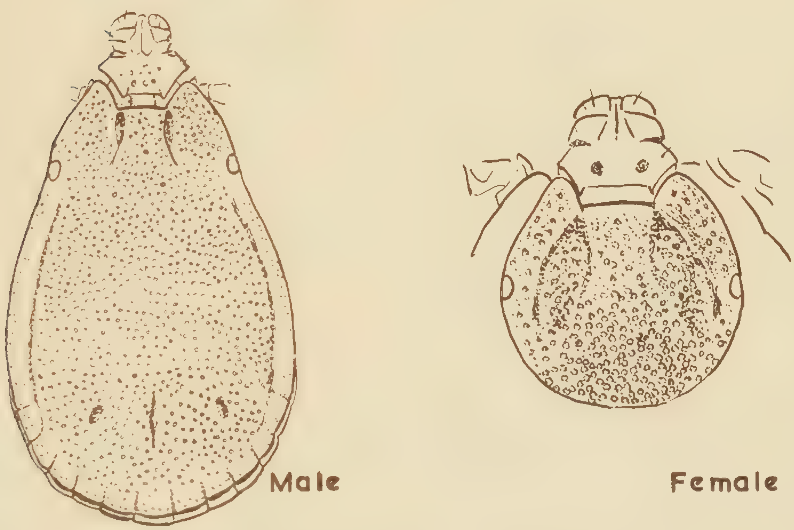
HAEMAPHYSALIS LEACHI.



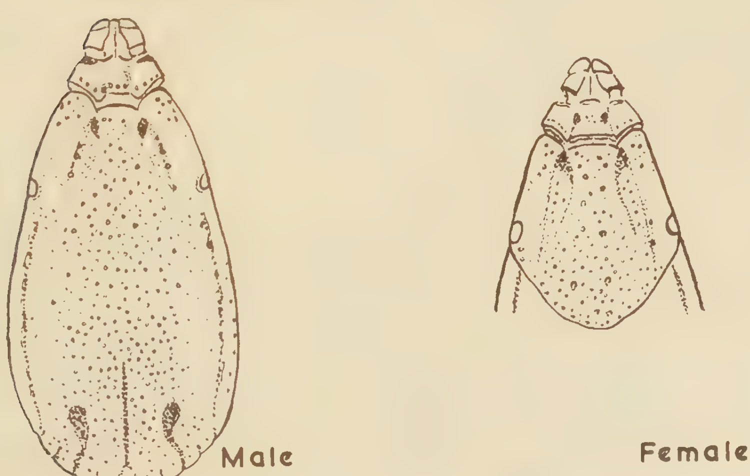
HYALOMMA sps.



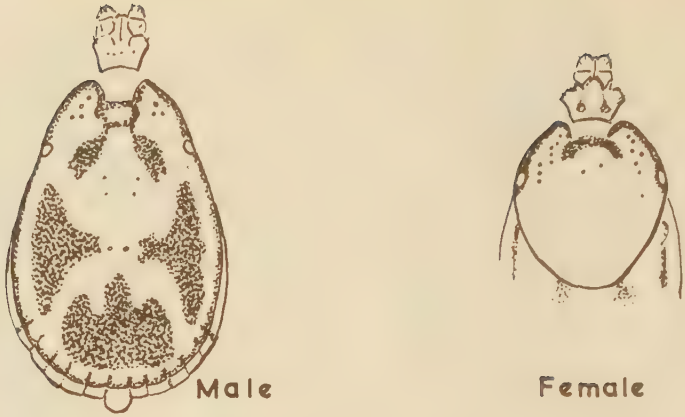
RHIPICEPHALUS APPENDICULATUS.



RHIPICEPHALUS CAPENSIS.

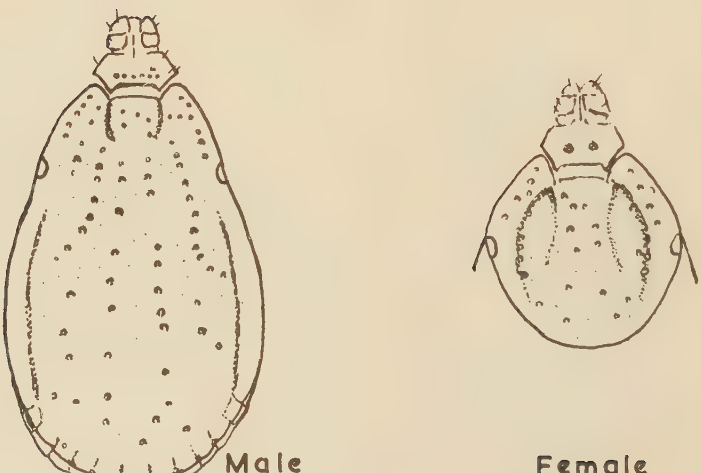


RHIPICEPHALUS NEAVEI.



RHIPICEPHALUS PULCHELLUS.

RHIPICEPHALUS SANGUINEUS.



RHIPICEPHALUS SIMUS.

parasite, which can also prove fatal to domestic birds.

The control of these ticks is best achieved by disinfection of premises. This can be done by spraying, fumigating or even by burning with a blow-lamp. If the house is a cheap thatch and wattle structure and the infestation heavy, it would probably be best to burn it and rebuild. Before transferring birds to new or uninfected quarters, it is advisable to quarantine them for ten days in boxes or temporary shelters which are also burned later, in view of the fact that the larval stage can remain on a fowl for as long as this.

IXODIDÆ—THE HARD TICKS

Amblyomma gemma, Donitz.

Description.—This species, together with some of the other members of the genus *Amblyomma,* is amongst the most striking of all the ticks. This is due to the brightly coloured shields of both sexes. The outline of the pattern can be seen in the illustration; the colours are dark brown on orange. It is medium sized and a three-host tick.

Distribution.—In Kenya it is confined to the drier parts of the Colony in the north, east and south. The Highlands and Nyanza in the west are not suited to this species.

Hosts and Habits.—In areas where it occurs it is common on cattle, less numerous on sheep, and rare on goats. In the Northern Frontier it is found quite frequently on camels. Like most ticks of this genus the adults prefer to feed on the under-parts of the animal's body—on the udder and scrotum especially.

Disease.—Some years ago in an experiment at Kabete, this tick was proved capable of transmitting heartwater. It is not, however, considered to be the chief vector of this disease—*A. variegatum* holds this "honour" in East Africa.

Amblyomma variegatum, Fabricius—The Variegated Tick or the Tropical Bont Tick

Description.—This is another medium-sized, three-host tick, rather similar to the last. The scutum has brownish-black markings on a coppery-orange ground. Unlike *A. gemma* this species has only dark-coloured festoons (i.e. segmented areas around the posterior margin of males). The illustrations will show the different colour patterns and facilitate identification.

Distribution.—Abundant throughout the Highlands and western Kenya. It is not common in most areas of the Coast Province, though it does occur in some parts; it is absent from the drier eastern and northern parts of the Colony where *A. gemma* is quite at home. However, where the humidity is high enough and conditions suitable, *A. variegatum* can occur from sea-level up to at least 8,500 ft, in the vicinity of Timboroa.

Hosts and Habits.—Cattle, sheep and goats chiefly, amongst domestic stock. It chooses the under-parts of the host's body on which to feed.

Disease.—This species is the common vector of heartwater, a rickettsial disease of cattle and sheep, frequently met with in this Colony. It can also carry Nairobi sheep disease.

Boophilus (*Palpoboophilus*) *Decoloratus,* Koch.—The Blue Tick

Description.—The female, when engorged, is bluish in colour, with a yellowish-brown shield. The engorged female frequently has a slight constriction about the middle. The species is characterized by its pale yellow legs and very short mouth-parts. The male is a very inconspicuous pale brownish-yellow creature; to find it one should look underneath the engorged female at the point of attachment.

This is the only one-host tick with which we have to deal here in this country.

Distribution.—A moist climate seems to be the most important ecological factor governing the distribution of this species. It is at home on the upland plateau and in the forest glades. It flourishes in many parts of the Highlands and is present in Nyanza; it occurs also in Masai but avoids the open plains of that reserve. The Northern Frontier and the dry eastern parts of the Colony are unsuited to this tick. Its distribution is, in many respects, similar to the variegated tick mentioned above. It occurs from sea-level to an altitude of at least 8,000 ft.

Hosts and Habits.—This species is more selective in its choice of hosts than most. Cattle and horses are the animals usually affected. It occurs all over their heads, necks and bodies. Sheep, goats and dogs, occasionally act as hosts.

Disease.—Both redwater (*Babesia bigemina*) and gallsickness (*Anaplasmosis*) are usually transmitted in Kenya by this tick. In South

Africa it is recognized also as a possible vector of spirochaetosis of cattle, horses and sheep, caused by the organism *Spirochaeta theileri*, and also of the rickettsial disease in man usually referred to in this country as tick-bite fever or tick typhus. It has also been proved a vector of *Babesia trautmanni*, a blood parasite of pigs.

Hæmaphysalis leachi, Audouin.—The Dog Tick

Description.—This is a fairly small species of three-host type of tick; in colour it is light brown. One of the characteristics of ticks belonging to this species is that they lack eyes. It is also distinguishable by the short mouth-parts and the shape of the palps, which give the head a triangular appearance.

Distribution.—The dog tick is widely distributed throughout Kenya and, in fact, throughout Africa as a whole. In this Colony we have records from places as far apart as Kwale in the Coast Province, Namanga in South Masai, Kisumu on the shores of Lake Victoria, and Timau on the foothills of Mt. Kenya.

Hosts and Habits.—This species is essentially a parasite of dogs and cats; it feeds also on many of the wild carnivores.

Disease.—Piroplasmosis of dogs, or tick fever, as it is commonly called, is carried by the dog tick. The organism causing this disease, *Piroplasma canis*, is capable of passing from one generation of tick to the next through the eggs. Tick fever (or tick typhus) of man, a rickettsial disease quite different from tick fever of dogs, has also been proved capable of transmission by this species.

Hyalomma species—Bont-legged Ticks

Description.—Here in East Africa certainly four different species of bont-legged tick occur. There are others which have yet to be reared and properly classified. In habits and appearance all these species are very similar, and this no doubt accounts for the confusion, which has always existed in the identification and nomenclature of many of the species belonging to this genus. However, in this instance, it will be sufficient to deal with them as a whole, using only their generic name. The *Hyalomma* are distinguished by their banded legs, their uniformly black shields in both sexes, "beady" hemispherical eyes and by their long, narrow mouth-parts.

For the most part, on cattle, the *Hyalomma* are three-host ticks. Some species are, however, inconsistent. If they feed on rodents they may behave as two-host ticks, whereas the same batch of ticks, if fed on a bovine, would be three-host ticks.

Distribution.—For the most part, *Hyalommas* are confined to the drier parts of East Africa. They are abundant in some of the lower areas of the Rift Valley, and the semi-arid parts of the Yatta and coastal hinterland. In many districts of the Northern Frontier Province, which are little more than desert and wastes of lava rubble, these ticks predominate.

Hosts and Habits.—Cattle, camels and sheep. The bont-legged tick usually chooses a more or less hairless part of the host's body on which to feed; under the tail is a particularly favoured site, also on the udder, scrotum and between the "toes".

Disease.—Under experimental conditions at Kabete three different species of *Hyalommas* have been proved capable of transmitting East Coast fever. The bont-legged tick has also been incriminated in the carrying of tick-bite fever of man. These ticks, with their long mouth-parts, bite deeply, and are sometimes the cause of sores and lameness due to secondary invasions by bacteria.

Rhipicephalus appendiculatus, Neumann.—The Brown Tick, the East Coast Fever Tick

Description.—There is no simple way of describing, in common terms, this species so as to make its identification certain. To a person who has not made a study of ticks, it appears merely as a reddish-brown tick, which, in fact, might be any one of half a dozen species or more. However, with the aid of the illustration the following notes should prove of assistance. Eyes are present, as in all members of this genus. The head and mouth-parts are not particularly long as in *Hyalommas*. The punctations are numerous, irregular in size, fairly evenly dispersed but with a tendency to thin out and become sparse towards each side of the shield.

Distribution.—The distribution of this species is perhaps better known than any other in this Colony, due to its economic importance as a vector of diseases. Rainfall is quite obviously a limiting factor in its distribution. To maintain itself in a district an average rain-

fall of 20 inches or more appears to be necessary. As might be expected here in the tropics, this minimum is about five inches per annum more than is required by the same species of tick in the Union of South Africa.

The brown tick is common throughout Nyanza, and in many parts of the moister parts of the Central Province at elevations between 4,800 ft. and 7,000 ft.: it can occur below these altitudes, and certainly considerably above them in localities with sheltered and favourable conditions. Practically the whole of the Northern Frontier is quite unsuited to this tick.

It occurs in patches in many parts of the coastal belt, between the Tanganyika border and a point a little north of Malindi. Further inland it occurs around the Teita Hills and on the Sagala Hills just south of Voi. In Masai it is common in the western part of the reserve known as Trans Mara and up-stream along the Mara River: also between Athi River and Kedong in the Ngong area, and again between Konza and Kima. The greater part of this reserve, however, apart from the areas just mentioned, is free of this tick. Its distribution in the Uasin Gishu and Trans Nzoia districts has been fairly general but dipping is bound to eradicate it eventually in many areas. At the higher altitudes in these districts it becomes less frequent. The Kinangop plateau is unsuitable for *R. appendiculatus* but in parts of the Karati Forest it does occur. In the higher parts of the Rift Valley itself, it occurs in certain isolated areas; for example, it has been collected on farms at Gilgil, Elmenteita, Nakuru, Njoro and Naivasha.

Hosts and Habits.—Cattle, sheep and goats. It is a three-host tick and is most frequently found in the ears of the host.

Diseases.—This species is well known to be the chief vector of East Coast fever caused by the parasite *Theileria parva*. Its method of transmitting this disease is described in an earlier article in this series, "East Coast Fever and Related Diseases" (this JOURNAL, Vol. 12, 1947, p. 167). This tick is also capable of transmitting redwater (*Babesia bigemina*); Nairobi sheep disease; *Theileria mutans*, a protozoon disease of cattle which runs a mild course in this country; and in South Africa, louping ill, which is another virus disease of sheep. Tick-bite fever in man can also be carried by this versatile parasite.

Rhipicephalus capensis, Koch.—The Cape Brown Tick

Description.—A deep-brown tick with medium-sized, densely packed punctations, evenly distributed over the shield. Lateral angles on the hind part of the head, more acute than in *R. appendiculatus*. It is a three-host tick.

Distribution.—This species has a rather restricted distribution in Kenya; it confines itself for the most part to the higher moist districts. Most of our records are from places along the eastern edge of the Rift Valley from Limuru northwards to Thomson's Falls, and also from places stretching across the Rift Valley itself in the vicinity of Lakes Naivasha, Elmenteita and Nakuru. It also occurs up the western side of the valley to Mau Summit but it seems less common this side of the Rift.

Hosts and Habits.—Cattle usually, also dogs. It generally feeds on the underside of the body and on the tail.

Diseases.—*R. capensis* is another of the ticks which has been shown capable of carrying East Coast fever.

Rhipicephalus Evertsi, Neumann.—The Red-legged Tick

Description.—Colour, dark brown, with numerous large punctations, often contiguous, giving a shagreened appearance. Eyes, dark and hemispherical in shape. This is one of the easiest of the species to identify on account of its bright, saffron-coloured legs. It is a two-host tick.

Distribution.—The red-legged tick is widely distributed throughout the Colony. It has been recorded from the deserts in the Northern Province, from the coastal areas and from the open plains, as well as from the forested "scarps" of over 8,000 ft.; one might, in fact, come across it almost anywhere.

Hosts and Habits.—Cattle, sheep, goats and horses. There are also records of it from a donkey at Namanga and from a camel in the Northern Frontier. A favourite site of attachment with this species is around the anus; the immature stages are frequently found deep in the ears.

Disease.—The following diseases have been found transmissible by this species: East Coast fever; redwater of cattle; *Theileria mutans*;

biliary fever in horses caused by the parasite *Nuttalia equi*; and spirochaetosis caused by *Spirochaeta theileri*.

Rhipicephalus neavei, Warburton

Description.—A brown tick, small to medium in size, with punctations rather similar to those of *R. appendiculatus,* but tending to disappear in front of the eyes. The chief distinguishing feature is again the shape of the angles at the sides of the hind-part of the head. Compare these with those in the illustration of *R. appendiculatus. R. neavei* is a three-host tick.

Distribution.—This species is very common in many of the drier parts of the Colony. The areas it inhabits form a belt around the Kenya Highlands on the north and east.

Hosts and Habits.—Cattle, sheep, goats and to a lesser extent, camels. Like the brown tick it is frequently found in the ears of cattle (*R. neavei* and *R. appendiculatus* are only seldom found together in the same area).

Disease.—Under experimental conditions at Kabete, this tick proved to be an efficient vector of East Coast fever. Why this should not be so under field conditions is not yet understood.

Rhipicephalus pulchellus, Gerstacker—The Zebra or Yellow-backed Tick

Description.—The characteristic ivory-coloured markings on the shield of *R. pulchellus* make this another easily recognizable species. It is a three-host tick.

Distribution.—In Kenya this tick does not appear to occur west of the Rift Valley. It is, however, an extremely common tick in many of the drier areas, not only on the open plains, but also in the well-wooded districts.

Hosts and Habits.—Cattle, sheep, goats, dogs, horses and camels. On cattle this tick may be found feeding on the under-parts of the body, on the tail, and under the tail; it may also be found on the legs.

Diseases.—So far *R. pulchellus* has not been proved to carry any disease.

Rhipicephalus sanguineus, Latreille—The Kennel Tick, the Brown Dog-tick, the European Brown Tick

Description.—This is yet another tick which is brown in colour. It is easily distinguished from *H. leachi,* the other common tick found on dogs, by being darker and by the presence of a pair of eyes. Punctations are variable in size, the smaller ones being relatively dense and the larger more scattered. The three posterior grooves towards the end of the shield are characteristic.

Distribution.—Records show it to be present in widely separated areas, from Moyale on the Abyssinian border to Namanga on the Tanganyika border, and in a fairly large number of places in the Highlands. It is most common along the Kenya coast from Kilifi southwards to the Tanganyika border. It is a three-host tick.

Hosts and Habits.—Dogs usually; cattle, sheep and goats rarely. This tick is well known for its ability to infest houses and kennels where it hides in cracks and crannies. In wood and iron buildings it is sometimes no easy task to get rid of the pests.

Disease.—Tick fever (*Piroplasma canis*) in dogs. Though not a common parasite of cattle, it has been shown capable of transmitting gall-sickness (*Anaplasma marginale*). In North Africa it has been proved to transmit rickett-siosis of dogs (*Rickettsia canis*). It is also associated with the transmission of *Hepatozoan canis,* a protozoon parasite which causes a mild disease of dogs, and also with tick-bite fever in man. Concerning the last, it is particularly dangerous on account of its habit of infesting houses, especially those in which dogs are allowed to sleep.

Rhipicephalus simus, Koch.—The Black-pitted Tick

Description.—A very dark brown tick, glossy in appearance, and with numerous very fine, shallow punctations interspersed with a few widely scattered large punctations. *R. simus* is a three-host tick.

Distribution.—Though records from the Northern Frontier are not as plentiful as elsewhere in Kenya, this species can be said to occur almost anywhere, whether it be hot and arid, cold and wet as at high altitudes, or hot and moist as at the coast where, incidentally, this species is particularly plentiful.

Hosts and Habits.—Cattle, dogs, sheep and goats. On cattle a favourite site of attachment is around the anus and in the brush of the tail. On dogs they attach almost anywhere on the body.

Disease.—This is another species which has been proved capable of carrying East Coast fever and also gallsickness (*A. marginale*). It can also transmit tick-bite fever of man.

A SIMPLE METHOD OF CALCULATING THE RELIABILITY OF RAINFALL

By J. Glover and P. Robinson, E.A. Agriculture and Forestry Research Organization

(Received for publication on 20th May, 1953)

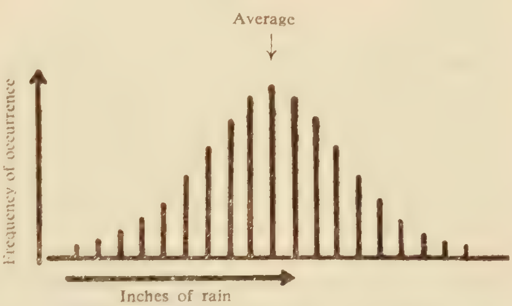
The accumulation of records by the E.A. Meteorological Department now makes it possible to investigate rainfall variation from year to year. The farmer in East Africa, who suffers more from too little rather than too much rain, is much more concerned with its reliability than any other aspect. While investigating the variation we therefore concentrated on the problem of measuring how often the farmer can expect a certain minimum total of rain in a season. As everyone knows, averages of rainfall are very misleading and they are certainly of very limited value in comparing one place with another. For example, two farms may each have an average of 20 inches of rain in the same "rainy" season, yet on one farm the records show the extremes of the seasonal rains during, say, the last 20 years to be from 10 to 30 inches while on the other, over the same period, the range may be only 15 to 25 inches. Of the two, the second farm has undoubtedly the more satisfactory rainfall, yet it is not shown in a statement of averages. Consider the same two farms and suppose both grow a crop which requires a minimum of about 15 inches of rain in the season to give an adequate yield. The second farm is likely to get this frequently, for as the figures show it has not failed in the 20 years the records have been kept. The first farm, however, must sometimes fail to receive it, for in one year at least it received only ten inches. It is obvious, therefore, that the owner of this farm is, or should be, concerned with the question of how frequently the farm will receive less than 15 inches of rain in the season for it may mean the difference between profit and loss.

We have published elsewhere [1] the technical details of the method of measuring the reliability of rain, and we have also prepared maps of the reliability of annual rainfall for East Africa as a whole, which we hope to publish shortly. We are also preparing maps of the reliability of seasonal rainfall, but as this will take some time we feel that interested farmers might like to calculate the reliability of rainfall on their own farms.

This paper is therefore concerned solely with a simple method which requires the use of elementary arithmetic. The method gives results which are not strictly correct but, as the investigations have shown, they are not seriously in error from a practical standpoint, for the use of complicated mathematical procedures to improve the accuracy of the results lead in general only to slight changes in the values which are of little or no practical importance. Those who wish to read about the more mathematically precise method should consult the original paper mentioned above.

During our investigation we observed that the seasonal and annual falls in East Africa, as measured by any rain gauge, appeared to follow the "normal curve of errors". This curve is shown in Fig 1; the rainfall is

FIG. 1



measured along the base and the vertical axis measures the number of times such falls occur. It can be seen that about half the total falls are above average and half below, with the majority close to the average and becoming less frequent as the distance from the average increases. In general, a few years' records do not show this when plotted on a graph but these can be shown mathematically to conform to the regular pattern. It is therefore sufficiently accurate for our purposes to assume that rainfall totals follow this "normal" curve. The constants defining this theoretical curve can easily be determined by simple arithmetic and the probability of obtaining values above or below any selected point can be determined. The constants are the average and a measure of variation about this average, the "*standard deviation*". The calculation of the first is normal practice and the calculation of the

second is shown in Table I. This table shows the actual seasonal total records obtained from a rain gauge at a place in Tanganyika. The records covered a period of 11 years.

TABLE I

Seasonal total inches of rain	Difference between average and the seasonal total	Square of the difference between the average and the seasonal total
21.7	3.2	10.24
18.7	6.2	38.44
27.1	2.2	4.84
20.0	4.9	24.01
45.1	20.2	408.04
19.2	5.7	32.49
28.3	3.4	11.56
30.2	5.3	28.09
20.7	4.2	17.64
23.6	1.3	1.69
19.0	5.9	34.81
Total for 11 years 273.6		611.85 (Total sum of squares)
Average for 11 years 24.9		

The average is obtained in the usual way; in this case it is 273.6/11 or 24.9 inches. The difference between the actual rainfall each year and the average is then placed in the second column: for example, in the first year of the records 21.7 inches fell; this subtracted from 24.9 gives 3.2 inches. This column shows the wide deviations from the average in the period under review. The figures in themselves do not convey much information about the variation so they must be treated further so that the variation is expressed in standard measure. To do this each difference shown in the second column is squared and written down in the third column; for example, $(3.2)^2 = 10.24$ and so on. This column of squares is then added to give the total sum of squares (611.85). This total is then divided by one less than the number of records used in the calculation. As 11 records were used the total sum of squares is divided by ten. If 19 years had been used the total would be divided by 18, and so on. The square root of the total sum of squares divided by one less than the number of records is called the *standard deviation*. It is a measure of the variation about the average. In this case, the total divided by ten gives 61.185 and the square root of this is 7.82 which is the *standard deviation*.

If we now wish to find out how often the seasonal rain is likely to be below a selected level we use the figures already calculated, the average and the standard deviation to calculate what we call the "*standardized difference*". The calculation of the "standardized difference" is only a means of reducing different averages and standard deviations to a uniform scale which can be looked up in Table II. This table gives the probabilities of obtaining a record or records less than the selected level whose standardized difference has been calculated.

TABLE II

Standardized difference	Percentage probability	Standardized difference	Percentage probability
3.00	0	0.70	24.2
2.50	0.6	0.65	25.8
2.00	2.3	0.60	27.4
1.50	6.7	0.55	29.1
1.40	8.1	0.50	30.9
1.30	9.7	0.45	32.6
1.20	11.5	0.40	34.5
1.10	13.6	0.35	36.3
1.00	15.9	0.30	38.2
0.95	17.1	0.25	40.1
0.90	18.4	0.20	42.1
0.85	19.8	0.15	44.0
0.80	21.2	0.10	46.0
0.75	22.7	0.05	48.0
		0.00	50.0

To take a practical example, assume that we wish to know how often the seasonal rainfall shown in Table I is likely to be below 20 inches. The selected level, 20 inches, is first subtracted from the average, 24.9 inches, and the difference is divided by the standard deviation, 7.82.

$$\text{Thus } \frac{24.9 - 20}{7.82} = \frac{4.9}{7.82} = 0.63$$

The figure 0.63 is the "standardized difference".

Table II is now consulted: it will be found that 0.60 corresponds to a probability of 27.4 per cent and 0.65 to 25.8 per cent. The difference of .05 in the standardized difference in this region therefore corresponds to a difference of 1.6 per cent in probability. From this it will be seen that a difference of .03 corresponds to a difference of $3/5 \times 1.6$ or approximately 1.0 per cent probability. Subtracting this from 27.4 per cent, we find that a standardized difference of 0.63 corresponds with a probability of 26.4 per cent. This is, 26.4 per

cent of the time the total rain for the season is likely to be below 20 inches. This means that 26 to 27 years in a 100 the rainfall is likely to be below 20 inches. Although the estimate is likely to be less accurate for shorter periods we can also say it is likely to be less than 20 inches for five to six years in 20.

Sometimes we may want to know how often we are likely to obtain less than 30 inches of rain in the season. The calculation is similar. The standardized difference of 30 from the mean is $(30 - 24.9) / 7.82 = 0.65$. Looking this up in the table it will be found that this corresponds to a probability of 25.8 per cent. In this second case as 30 is *above* the average this is the probability of getting *above* 30 inches. So by subtracting the percentage probability from 100 per cent thus obtaining 74.2 per cent, we get how often the rainfall is likely to be below 30 inches.

Summarizing, the steps in the calculation are as follows:—

(1) Calculate the average (Total/number of readings).

(2) Calculate the *standard deviation* (the square root of the total of the squares of the deviation from the average divided by the number of readings less one).

(3) Calculate the standardized difference, which is the difference between selected level and average divided by the *standard deviation.*

(4) From the table determine the probability corresponding to this standardized difference. If the selected level is *below* the average, then the probability given in the table is the probability of getting *below* the selected limit; if the selected level is *above* the average, then the table gives the probability of getting a total rainfall *above* that limit. If this latter value is subtracted from 100 it gives the probability of getting *below* the selected level.

This method can be applied also to monthly totals instead of seasonal totals provided the average rainfall for the month is not too low. If the average is greater than 1½ times the standard deviation, the method should not lead to any serious error.

REFERENCE

[1] Glover, J., and Robinson, P.—*J. Agric. Sci.* (in press).

COMMONWEALTH BUREAU OF PASTURES AND FIELD CROPS

The Commonwealth Bureau of Pastures and Field Crops, which has been attached to the Welsh Plant Breeding Station, Aberystwyth, for the past 24 years, will be transferred to Hurley, Berkshire, in August, 1953, where it will be attached to the new Grassland Research Station, of which Dr. Wm. Davies is Director.

This Bureau, one of the ten Commonwealth Agricultural Bureaux, was founded at Aberystwyth in 1929, its first Consultant Director being Professor, now Sir George, Stapledon. For the first 20 years of its existence the Bureau was in charge of Dr. R. O. Whyte who was succeeded as Director in 1949 by Mr. A. G. G. Hill, formerly Director of the East African Agricultural Research Institute, Amani. The Bureau issues the well-known quarterly abstract journals *Herbage Abstracts* and *Field Crop Abstracts,* in addition to its other activities.

NOTES ON EAST AFRICAN APHIDS
III—APHIDS OF CRUCIFEROUS CROPS

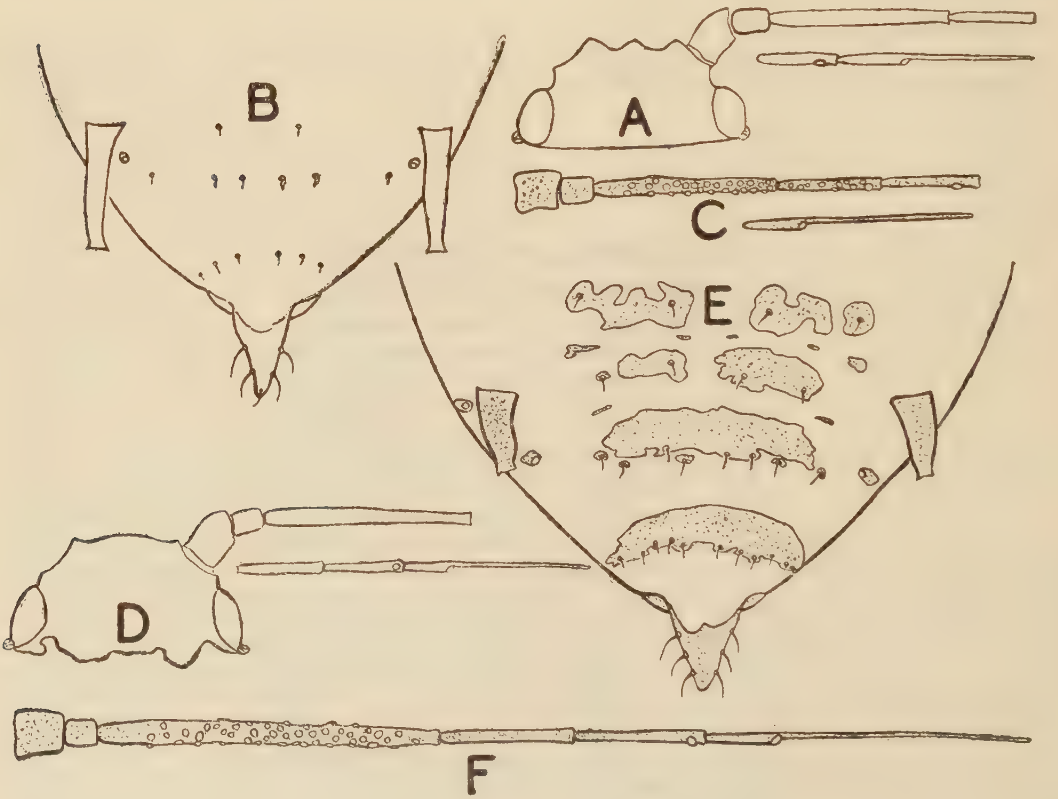
By V. F. Eastop, E.A. Agriculture and Forestry Research Organization

(*Received for publication on 12th May, 1953*)

Only two aphids are known to be specific on Cruciferous crops in East Africa. They are the Cabbage Aphid, *Brevicoryne brassicæ* (L.) which is covered with grey wax dust in life and *Lipaphis pseudobrassicæ* (Davis), a green aphid sometimes called the False Cabbage Aphid. The two species may also be distinguished by the relative size and shape of the siphunculi and cauda. In microscope preparations *brassicæ* shows a dorsal abdominal pattern of transverse black bars which is absent in *pseudobrassicæ*. In addition to the characters given above the winged forms may be separated by the position of the secondary rhinaria, which are confined to the long third antennal segment in *brassicæ* and which are present on the third, fourth and sometimes also the fifth segments in *pseudobrassicæ*. The latter differs from *Myzus persicæ* (described in Part II of this series), another green aphid common on *Cruciferæ*, particularly in the shape of the front of the head.

A–C, *Lipaphis pseudobrassicæ* (Davis); A, head and antenna of aptera; B, posterior part of abdomen of aptera; C, antenna of alata.

D–F, *Brevicoryne brassicæ* (L.); D–F as A–C.



THE EAST AFRICA MILK RECORDING SCHEME

The scheme has recently been reorganized, with its own finances, staff, secretary and equipment. The Royal Agricultural Society, through the East Africa Stud Book Executive Committee, continues to house the scheme, and to be responsible for its management and conduct. The gap between the £3,500 of fees subscribed by 140 members and the £5,000 which it costs to maintain the scheme in operation, is bridged by a Government subsidy of £1,500. About 10,000 cows are at present recorded, but it is hoped that there will be many more entries during the next year or two. Figures of all significant lactations, of notable ones, and of leading cows in various age groups, are published in three Journals with agricultural interests, the first two at monthly intervals and the latter at half-yearly intervals. A bid is being made for increased membership from the rapidly expanding dairy industry of Kenya. While most of the notable pedigree breeders are members of the scheme, it is felt that our membership could easily be doubled, and so make the recording scheme much more efficient. A list of leading cows in each breed during the past six months, and classified by age group, is now published, and it is hoped to continue this list each half-year, covering the preceding six months. Such figures will not be "stale" before publication and will represent lactations completed during the period under review.

A standardization of the lactation period at 305 days has been made to conform with National Milk Records of the United Kingdom, but in special cases, for mature and high-yielding cows, this period may be extended to 365 days.

The ordinary business of milk records, this maintenance and publication, will proceed. But what is becoming obvious is that in due course the archives will produce a mass of figures and information dealing with imported, country-bred and grade beasts, which can be of the highest value to dairymen and breeders.

If we can continue to obtain the backing and support of the dairy industry, of the Veterinary Department, and of Government, it is hoped that something valuable may eventually be obtained. Here are our leading cows for the last six months:—

JERSEYS LEADING COWS—MAY, 1953

	Milk lb.	Days	B.F. lb.	B.F. %
1. Senior Yearling—Pedigree				
i. Delamere Estates, Ltd., Soysambu Soysambu Ophelia ..	6,041.50	365	302.67	5.01
ii. Jalna Farm, Nairobi Hopelands Sweet Belle 3rd of Walia	4,951.75	305	248.08	5.01
2. Senior Yearling—Grade				
i. D. E. Fielden, Nakuru Mungai XI	5,358.00	365	282.37	5.27
ii. Col. E. Kentish Barnes, Elburgon Greenheart Nora ..	4,810.85	365	236.21	4.91
3. Junior Two-year-old—Pedigree				
i. Delamere Estates, Ltd., Soysambu Soysambu Marie Antoinette	6,164.50	331	319.94	5.19
ii. Roderick Lea, Ltd., Limuru Pearcelands Daisy 1st	5,739.85	305	307.08	5.35
iii. Delamere Estates, Ltd., Soysambu Soysambu Polly Peachum	5,643.50	365	290.08	5.14
iv. R. A. Clay, Elburgon Trefoil Croix's Cyclamen	5,882.20	250	280.58	4.77
4. Junior Two-year-old—Grade				
i. D. E. Fielden, Nakuru Kabai IV	8,795.00	365	423.92	4.82
ii. Maj. & Mrs. L. B. L. Hughes, S. Kinangop Mukeo Silver Moon	6,942.00	305	404.02	5.82
iii. D. E. Fielden, Nakuru Rongai VI	6,001.40	295	331.88	5.53
iv. R. A. Clay, Elburgon Trefoil Croix's Mary	6,644.00	281	311.60	4.69
5. Senior Two-year-old—Pedigree				
i. Ellver's Farm, Elburgon Victorious Dream ..	6,225.80	332	334.33	5.37
ii. Roderick Lea, Ltd., Limuru Eungella Jessabel ..	6,281.25	322	324.74	5.17
iii. Roderick Lea, Ltd., Limuru Grass Vale Lady Fowler 58th ..	5,705.25	365	322.92	5.66
iv. A. W. Symes, Kitale La Sergente's Dainty Lady	6,219.00	301	311.57	5.01
6. Senior Two-year-old—Grade				
i. D. E. Fielden, Nakuru Sabia VI	6,675.50	300	383.84	5.75
ii. J. C. Barnett, Molo Swara	6,640.25	305	367.89	5.45
iii. R. A. Clay, Elburgon Trefoil Maharaja's Marionette II ..	7,996.50	365	360.64	4.51
iv. D. E. Fielden, Nakuru Ngey III	6,044.50	291	356.63	5.90
7. Junior Three-year-old—Pedigree				
i. M. A. U. Heathcote, Kitale Bartonlodge Kitty ..	8,154.50	305	397.12	4.87
ii Jalna Farm, Nairobi Walia Parades Primrose	6,255.00	365	356.54	5.70
iii. Roderick Lea, Ltd., Limuru Eungella Jewell ..	7,036.00	286	328.58	4.67
iv. H. H. Peet, Nakuru Solai Victorious Morning Star ..	5,612.90	287	327.79	5.84

8. Junior Three-year-old—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. R. A. Clay, Elburgon Trefoil Maharaja's Eve II	10,545.50	338	563.13	5.34
ii. D. E. Fielden, Nakuru Jimma VI	7,838.00	365	484.39	6.18
iii. J. C. Barnett, Molo Nyagugi II	6,829.90	305	426.86	6.25
iv. D. E. Fielden, Nakuru Kenya IV	6,456.40	321	403.53	6.25

9. Senior Three-year-old—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Maj. & Mrs. L. B. L. Hughes, S. Kinangop Etty's Oxford's Morning Star ..	7,039.40	305	428.00	6.08
ii. Roderick Lea, Ltd., Limuru Trewlawney Sadie 2nd	7,468.75	305	402.07	5.37
iii. H. H. Peet, Nakuru Pride's Atomic Dainty	6,712.70	305	339.66	5.06
iv. The Lord Hugh Kennedy, Nanyuki Mons Tomahawks Madeline	7,159.00	362	325.73	4.55

10. Senior Three-year-old—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Lt.-Col. R. D. Gordon, Ol Joro Orok Nguno III	6,618.50	305	403.73	6.10
ii. D. E. Fielden, Nakuru Moshio V	5,928.00	305	363.39	6.13
iii. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Sixpence	6,100.00	261	334.89	5.49
iv. D. E. Fielden, Nakuru Moshio IV	5,476.60	252	316.09	5.79

11. Junior Four-year-old—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. R. A. Clay, Elburgon Lankhurst Ocarina ..	10,179.60	302	494.73	4.86
ii. R. A. Clay, Elburgon Trefoil Opal's Jasmin	7,356.25	280	389.88	5.30
iii. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Southernwood Noreen's Nestling	5,906.00	305	379.17	6.42
iv. Bryn Glas, Ltd., Nakuru Byefarm Bambi ..	7,608.10	305	367.47	4.83

12. Junior Four-year-old—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. D. E. Fielden, Nakuru Rubeni V	6,580.90	298	391.56	5.95
ii. D. E. Fielden, Nakuru Mugi II	5,658.00	266	343.44	6.07
iii. D. E. Fielden, Nakuru Samatia IV	6,292.60	252	298.27	4.74
iv. Osirna Jerseys, Limuru Famous Dream ..	5,849.90	299	276.12	4.72

13. Senior Four-year-old—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. R. A. Clay, Elburgon Dinarzade	8,257.75	305	470.69	5.60
ii. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Southernwood Star ..	6,809.00	246	400.37	5.88
iii. Lt.-Col. R. D. Gordon, Ol Joro Orok Rosendale Playful Pal	9,375.00	305	389.06	4.15
iv. Ellver's Farm, Elburgon Youthful Amazon ..	6,746.80	301	348.13	5.16

14. Senior Four-year-old—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. R. A. Clay, Elburgon Trefoil Furious Jane II	8,013.00	365	448.73	5.60
ii. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Taffy	7,236.00	305	447.18	6.18
iii. Major & Mrs. L. B. L. Hughes, S. Kinangop Daisy	9,310.40	304	420.83	4.52
iv. D. E. Fielden, Nakuru Mungai IV	6,364.20	360	379.94	5.97

15. Mature—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Wealden Water Baby	9,188.50	305	578.88	6.30
ii. P. N. Dearlove and Mrs. A. Jowitt, Ainabkoi Southernwood Designing Princess	7,616.50	239	437.19	5.74
iii. R. A. Clay, Elburgon Favorite of Brook Farm	7,064.50	287	401.97	5.69
iv. Roderick Lea, Ltd., Limuru Eungell Miss Marinora III	7,529.75	315	393.05	5.22

16. Mature—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. D. E. Fielden, Nakuru Kongoni I*	16,112.25	365	903.90	5.61
ii. Jalna Farm, Nairobi Osirna Cute Clare ..	12,606.75	329	651.77	5.17
iii. D. E. Fielden, Nakuru Jimma II .. .	10,875.10	320	623.14	5.73
iv. D. E. Fielden, Nakuru Sabia II .. .	11,618.50	365	606.49	5.22

AYRSHIRES—LEADING COWS—MAY, 1953

1. Under Two Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. David Lyall, N. Kinangop Kibsworthy Matilda ..	6,986.25	363	324.86	4.65
ii. Kabazi Estates, Nakuru Kabazi Emmaline ..	5,614.70	294	270.07	4.81

2. Under Three Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Hafod Estates, Limuru Hafod Marguerite ..	10,324.25	365	374.77	3.63
ii. Mtarakwa, Ltd., S. Kinangop Mtarakwa Polly . ..	8,042.10	338	365.11	4.54
iii. Mtarakwa, Ltd., S. Kinangop Mtarakwa Wren ..	9,302.40	278	336.60	3.61
iv. Mtarakwa, Ltd., S. Kinangop Mtarakwa Columbine	7,683.60	305	331.16	4.31

3. Under Three Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Hafod Estates, Limuru Dawn	8,343.50	351	315.38	3.78
ii. Cianda Estates, Ltd., Kiambu Ndito 15	9,227.00	340	310.03	3.36
iii. Raywell Farm, Ol Joro Orok Gilia	6,544.70	257	308.26	4.71
iv. Cianda Estates, Ltd., Kiambu Nyara 67	6,944.00	332	302.76	4.36

4. Under Four Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Mtarakwa, Ltd., S. Kinangop Mtarakwa Princess ..	9,205.30	289	382.02	4.15
ii. Strathmore, Ltd., Limuru Auchen Blanche 3rd	8,811.50	365	373.61	4.24
iii. Miss M. E. St. B. Atkinson, Limuru Preston Floralin ..	9,299.38	305	371.98	4.00
iv. Hafod Estates, Limuru Hafod Lavender ..	7,948.20	305	368.80	4.64

* This cow holds the Kenya Butterfat Championship for 1953.

5. Under Four Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Estates and Investments, Remainder Farm, Elburgon .. Mai IV	7,930.50	365	342.60	4.32
ii. Kivulini, Ltd., Molo Mary No. 8	7,623.70	264	340.78	4.49
iii. Maj. & Mrs. E. M. Kidner, S. Kinangop No. 28	5,840.40	305	320.05	5.48
iv. Lesirko, Ltd., Ol Kalou Lesirko 825	6,895.60	301	294.44	4.27

6. Under Five Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Gendin Farm, Ltd., Nakuru Gendin Miss Salome ..	8,570.80	305	347.12	4.05
ii. Pura Milk Dairy Farm, Naro Moru Denbigh Sholto ..	8,356.00	308	335.08	4.01
iii. Ellver's Farm, Elburgon Rangetane Daisy ..	6,841.70	305	306.51	4.48
iv. Strathmore, Ltd., Limuru Auchen Bertha ..	6,797.00	266	287.51	4.23

7. Under Five Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Kivulini, Ltd., Molo Mary 7th	10,325.20	261	409.91	3.97
ii. Hafod Estates, Limuru Canna	9,058.50	318	352.38	3.89
iii. Deloraine Estate, Ltd., Rongai Nderit 598	7,538.10	365	315.09	4.18
iv. Deloraine Estate, Ltd., Rongai Erongai 612	7,085.82	365	296.89	4.19

8. Mature—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Mtarakwa, Ltd., S. Kinangop Mtarakwa Maid 4th	12,760.70	364	525.74	4.12
ii. Kabazi Estates, Ltd., Nakuru Minsted Clip 2nd ..	12,534.00	365	501.36	4.00
iii. Hafod Estates, Limuru Killean Miss Gertrude	10,347.75	305	434.61	4.20
iv. Kivulini, Ltd., Molo Kivulini Phyllis 1st ..	8,098.10	307	396.81	4.90

9. Mature—Non-Pedigree (Grade)

	Milk lb.	Days	B.F. lb.	B.F. %
i. Maj. & Mrs. E. M. Kidner, S. Kinangop Red Mairu	9,796.30	363	476.10	4.86
ii. Hafod Estates, Limuru Teresa	11,343.50	365	441.26	3.88
iii. Hafod Estates, Limuru Cherry	11,645.25	365	436.87	3.70
iv. Hafod Estates, Limuru Claire	11,826.25	365	423.38	3.58

GUERNSEYS—LEADING COWS—MAY, 1953

1. Under Two Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Welcome Farm, Nairobi Ashdown Amanda ..	4,508.25	264	215.49	4.78

2. Under Two Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. J. D. Heath, Endebess Bonny	5,007.00	268	240.34	4.80

3. Under Three Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Blundell Estates, Nakuru Beaurepaire Princess Polly 9th	10,563.80	310	480.65	4.55
ii. Rhodora Estates, Ltd., Nakuru Valery 4th of Payhay	8,052.20	365	370.40	4.60
iii. Blundell Estates, Nakuru Beaurepaire Lady Richmond 28th ..	6,277.30	269	314.49	5.01
iv. Ondiri Farm, Kikuyu Ondiri Florissa ..	6,050.50	339	299.48	4.95

4. Under Three Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Blundell Estates, Nakuru Keroyit III	8,932.80	359	365.35	4.09
ii. S. S. Bastard, Sotik Sumeti	7,523.10	305	338.54	4.50
iii. Rhodora Estates, Ltd., Nakuru Sindette 122	6,876.20	359	309.43	4.50
iv. Rhodora Estates, Ltd., Nakuru Jemali 123	6,760.30	336	299.48	4.43

5. Under Four Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Olbonata, Ltd., Nakuru Olbonata Pauline ..	10,795.50	365	466.37	4.32
ii. Rhodora Estates, Ltd., Nakuru Rex's Rose 6th of Payhay	9,595.10	302	414.50	4.32
iii. Rhodora Estates, Ltd., Nakuru Malverley's Juna 8th	8,048.10	305	345.26	4.29
iv. Mrs. A. R. H. Crampton, S. Kinangop White Ladies' Bessie	6,132.50	305	273.51	4.46

6. Under Four Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Olbonata, Ltd., Nakuru Borana 551	9,728.00	365	505.85	5.20
ii. Olbonata, Ltd., Nakuru Lilgot 553	9,208.90	301	442.95	4.81
iii. Rhodora Estates, Ltd., Nakuru Jessumul 97	8,364.40	336	382.32	4.59
iv. Ondiri Farm, Kikuyu 2.60	6,395.50	356	363.26	5.68

7. Under Five Years—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Olbonata, Ltd., Nakuru Olbonata Sundew ..	9,386.20	361	495.59	5.28
ii. Mrs. I. Clarke, Nyeri Nyeri Lady Charming	6,908.60	339	277.73	4.02
iii. H. J. Gibbs, Timau Lugilada Snowdrop ..	4,577.75	310	216.99	4.74

There is no 4th in this class

8. Under Five Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. Olbonata, Ltd., Nakuru Taibiss 556	8,123.00	305	372.03	4.58
ii. D. A. L. Holden, Sotik Isiolo 196	6,730.10	363	295.45	4.39
iii. Blundell Estates, Nakuru Tilito	6,314.70	305	294.23	4.65
iv. Geoffrey Ireland, Ltd., Nakuru Chepto 286	5,260.00	305	276.68	5.26

9. Mature—Pedigree

	Milk lb.	Days	B.F. lb.	B.F. %
i. Olbonata, Ltd., Nakuru Olbonata Heroine's Honey	10,016.40	360	454.74	4.54
ii. M. Cunningham Reid, Elmenteita Caradoc Angelic 1st	7,113.00	305	332.18	4.67
iii. Mrs. I. Clarke, Nyeri Nyeri Lady Beautiful	7,092.20	318	314.89	4.44
iv. Welcome Farm, Nairobi Drakesbrook Bellbird	5,811.75	277	259.79	4.47

10. Mature—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. J. D. Heath, Endebess Peggy	8,823.00	312	434.97	4.93
ii. Olbonata Ltd., Nakuru Bungoma 340 ..	8,489.00	365	432.94	5.10
iii. Rhodora Estates, Ltd., Nakuru Nduos 3	10,350.40	302	420.23	4.06
iv. Rhodora Estates, Ltd., Nakuru Rumaval	9,152.00	320	404.52	4.42

FRIESLANDS—LEADING COWS—MAY, 1953

1. Under Two Years—Grade

	Milk lb.	Days	B.F. lb.	B.F. %
i. W. Prentice, Nakuru Hilda	7,116.00	305	284.64	4.00

	Milk lb.	Days	B.F. lb.	B.F. %
2. Under Three Years—Pedigree				
i. B. R. McKenzie, Nakuru Tusogo Arch Willowmedes	11,455.80	365	461.67	4.03
ii. B. R. McKenzie, Nakuru Karirana Gonda ..	11,050.80	365	417.72	3.78
iii. B. R. McKenzie, Nakuru Tusogo Arch Posh ..	8,940.30	308	346.88	3.88
iv. B. R. McKenzie, Nakuru Tusogo Arch Typette	9,187.70	275	336.27	3.66
3. Under Three Years—Grade				
i. J. W. Etherington, S. Kinangop Atlanta	7,718.50	352	298.71	3.87
ii. J. W. Etherington, S. Kinangop Nevada 248	8,024.30	365	285.67	3.56
iii. Manera Farm, Naivasha E.T. 110	6,288.00	365	260.32	4.14
iv. Pease Estates, Njoro 362	4,255.50	300	242.99	5.71
4. Under Four Years—Pedigree				
i. B. R. McKenzie, Nakuru Tusogo Lod Moline ..	15,990.80	365	508.51	3.18
ii. B. R. McKenzie, Nakuru Tusogo Arch Godetia	12,343.20	365	471.51	3.82
iii. H. C. D. Hayter, Nakuru Karirana Ethel ..	10,809.75	314	397.80	3.68
iv. B. R. McKenzie, Nakuru Karirana Juniper ..	10,602.70	311	358.37	3.38
5. Under Four Years—Grade				
i. MacKenzie Estates, Njoro Langok 78	9,827.50	290	346.91	3.53
ii. W. Prentice, Nakuru Josie	7,694.10	365	295.45	3.85
iii. Manera Farm, Naivasha A. 182	7,055.00	365	287.14	4.07
iv. W. Prentice, Nakuru Pixie	7,778.30	305	286.24	3.68
6. Under Five Years—Pedigree				
i. B. R. McKenzie, Nakuru Tusogo Lod Wilful ..	13,911.80	365	485.52	3.49
ii. B. R. McKenzie, Nakuru Karirana Elaline ..	9,904.00	266	301.08	3.04
iii. Tatton Farm, Njoro Tusogo Lod Fleur ..	8,819.80	245	298.99	3.39
iv. Belvedere Model Dairy, Kikuyu Belvedere Vamp ..	8,565.80	265	292.09	3.41
7. Under Five Years—Grade				
i. Manera Farm, Naivasha E.T. 166	10,628.00	305	396.42	3.73
ii. Manera Farm, Naivasha A. 103	10,765.00	365	378.93	3.52
iii. Smethcote Farm, Menengai Kamulat	9,598.00	305	375.28	3.91
iv. Manera Farm, Naivasha A.V. 806	10,871.50	365	372.89	3.43
8. Mature—Pedigree				
i. B. R. McKenzie, Nakuru Karirana Moonstone	21,980.60	365	636.45	2.85
ii. B. R. McKenzie, Nakuru Karirana Ebony ..	16,526.90	332	517.29	3.13
iii. B. R. McKenzie, Nakuru Karirana Julep ..	13,681.70	307	488.44	3.57
iv. B. R. McKenzie, Nakuru Karirana Jenny ..	15,774.50	307	485.85	3.08
9. Mature—Grade				
i. Manera Farm, Naivasha 768	16,189.65	365	610.34	3.77
ii. Manera Farm, Naivasha X. 115	22,308.50	365	602.33	2.70
iii. Manera Farm, Naivasha V. 673	11,429.50	365	536.33	4.78
iv. Manera Farm, Naivasha X. 797	14,274.10	365	509.49	3.57

RED POLLS—LEADING COWS—MAY, 1953

	Milk lb.	Days	B.F. lb.	B.F. %
1. Under Four Years—Grade				
Mrs. S. A. Wilson, Ol Kalou Kanini 35	5,128.00	321	219.99	4.29
2. Under Five Years—Grade				
Mrs. S. A. Wilson, Ol Kalou Dumumu 29	6,821.50	305	268.08	3.93
3. Mature—Pedigree				
H. C. Coltart, Njoro Scott Patricia ..	5,810.00	251	203.35	3.50
4. Mature—Grade				
Mrs. S. A. Wilson, Ol Kalou Tibbis 22	6,912.50	332	293.09	4.24

SHORTHORNS—LEADING COWS—MAY, 1953

	Milk lb.	Days	B.F. lb.	B.F. %
1. Under Three Years—Grade				
H. H. Peet, Nakuru Blossom 5th	8,115.10	364	308.37	3.80
2. Under Five Years—Grade				
H. H. Peet, Nakuru Berenice II	9,445.30	305	387.26	4.10
3. Mature—Pedigree				
H. H. Peet, Nakuru Solai Rosebud ..	7,852.80	286	309.40	3.94
4. Mature—Grade				
P. F. Roller, Ol Joro Orok Binki	6,390.60	305	314.42	4.92

CROP RESPONSES TO FERTILIZERS AND MANURES IN EAST AFRICA

(*Report of a Conference of the Specialist Committee on Soil Fertility*)

1. Introduction by Sir Bernard Keen, F.R.S.

2. Review of Papers and Discussion by D. W. Duthie

3. Summaries of Papers

INTRODUCTION

The papers and discussion summarized in the following pages are the record of a considerable amount of work that has been brought together and examined by a committee of specialists from territorial and interterritorial centres. The members of the committee themselves prepared the 22 papers, which they critically discussed at a two-day meeting held at the Headquarters of the East African Agriculture and Forestry Research Organization in February, 1953. In all, 30 attended the conference including, besides the paper-readers and observers, Dr. E. M. Crowther, Deputy Director, Rothamsted Experimental Station, and Professor Matthias Stelly of the University of Georgia, U.S.A.

Besides the Agricultural Departments of Kenya, Tanganyika, Uganda and Zanzibar and the East African Agriculture and Forestry Research Organization, papers came from the Overseas Food Corporation, the Tea Research Institute of East Africa, and Messrs. African Explosives and Chemical Industries (E.A.), Ltd. The crops covered included the standard annual arable crops: wheat, maize, elusine, sorghum, groundnuts, cotton; grass and pasture; plantation and perennial crops—sisal, coffee, tea, and pyrethrum. A considerable volume of the recent results under discussion came from the field experiments of the Overseas Food Corporation, and from two Colonial Development and Welfare Schemes known respectively as the Native and Kenya Highlands Fertilizer Schemes. These two schemes, which belonged to the East African Agriculture and Forestry Research Organization and the Kenya Department of Agriculture respectively, worked in the closest collaboration. The former conducted its experiments on African areas, where peasant and subsistence farming is practised, notably in the provinces around Lake Victoria, while the latter covered the European farming areas in the Kenya Highlands and thus dealt with an agricultural system very different in its economic and agronomic structures from the African one.

The fertility aspects of both Colonial Development and Welfare Schemes, however, like those of the Overseas Food Corporation and departmental experiments, were all much the same. Attention was concentrated on the response to fertilizers, notably phosphatic compounds including imported superphosphates and the locally made "sodaphosphate" manufactured from the extensive phosphate rock deposits at Tororo, Uganda, and the soda deposits of the dried-up lake at Magadi, Kenya.

The concentration of the field experiments mainly on artificial fertilizers was, and is, justified. It is not suggested that their use in African peasant conditions is a short-range possibility. The purpose of the experiments is, rather, to provide the information about the fertility status of tropical and sub-tropical soils that must be available if the introduction of permanent improvements is to be based on something besides intuition. It is not generally realized how meagre is our knowledge of tropical soils in comparison with the extensive information on soils in the temperate zone. Fortunately, there is increasing realization of the danger of applying the techniques of temperate zone farming to the tropics, without previous critical tests. One important incidental function of the field experiments discussed below is to provide those tests, in addition to supplying extensive field data for comparison with the results of laboratory researches on the soils and crops. Some eight of the 22 papers were specifically devoted to this fundamental aspect, covering such factors as the relation of soil type and climatic environment to yield responses, the measurement of fertility levels, the availability of added plant nutrients and the effects of balance and unbalance of plant nutrients on crop growth and yields.

The account that follows brings out these two points: that territorial and—more recently—interterritorial activities in East Africa have produced a considerable quantity of practical and scientific information on soil fertility; that the value of this information for both local and East African application, is much enhanced

by assembling the results for periodic full and critical discussion by a specialist conference. Finally, such a discussion also serves to bring out the gaps that still exist, and to suggest how to deploy existing facilities to the best advantage.

REVIEW OF THE WORK OF THE CONFERENCE

Phosphate

In his historical paper on the use of artificial fertilizers in Kenya, Gethin Jones points out that, during the war years, the need for increased food production in Kenya emphasized the need for better farming methods, but the only practical possibility of introducing improved methods in any reasonable time was on the European farms. This involved the adoption of soil conservation methods, the starting of mixed husbandry, and a small but increasing use of artificial fertilizers, mainly phosphates applied to wheat. There were many instances of relatively small dressings of double supers resulting in greatly increased yields, and this made possible continued wartime production on such lands. It happens that the elevated regions which are climatically the most suitable for wheat have the most leached and highly unsaturated soils, which are deficient in "available" phosphate, and these generally gave good responses in farmers' strip trials.

At this time the importation of phosphates was severely restricted, and although supplies were obtained from Seychelles, large quantities of bones of cattle and game animals were collected, cotton seed ash was obtained from Uganda, and local scattered supplies of bat guano were exploited, the demand still far exceeded the supply. Steps were therefore taken to exploit the deposit of a primary phosphate (francolite) which was known to occur in Uganda near the Kenya border. It was proved that there are vast reserves of a readily mined ore, carrying 8 per cent to 35 per cent phosphoric oxide, with a working average of 25 per cent. But when the true manurial value of this ground rock phosphate was tested, it was found that only about half as much "early available" phosphate was liberated from it as compared with other commercially worked phosphate deposits, and it became apparent that Uganda phosphate was not suitable for application by itself to annual crops. However, after calcination with crude sodium carbonate from Lake Magadi, a sodaphosphate was produced which contained a high proportion of "citric-soluble" phosphate and a low content of water-soluble phosphate. On the basis of equivalent amounts of citric-soluble phosphate, sodaphosphate was found to be almost as effective as the materials of the superphosphate class, and, after numerous technical difficulties had been overcome in a pilot plant, full-scale production in two commercially owned plants was started within the past 18 months.

The main difficulty with fertilizer trials with phosphate is that the soils of East Africa have not yet all been typified, named, and mapped, an ideal which will require many years of intensive and extensive work. At present, doubts on the kind of soil on which a field trial is carried out lead to doubts as to the extent to which the results can be applied elsewhere in the district, and in other districts. In spite of this handicap, progress has been made in finding where phosphate is most likely to give economic returns, and, although much remains to be done, a very satisfactory start has been made. It should be borne in mind that phosphate is by far the most difficult fertilizer to investigate scientifically, since its reactions in the soil are complicated and are not yet fully understood. The results reported in these conference papers can be divided into four groups: very numerous field trials on a very wide range of crops and pastures; statistical interpretation, not only of each trial, but of groups of trials; soil survey in collaboration with field experimentalists in order to relate soil type to fertilizer response; and laboratory studies of the soil and plant in order to explain the effect of added phosphate in field trials.

It would be most convenient if chemical analysis of a soil would tell whether or not its productivity would be increased by adding phosphate, and Birch's work shows that it is not merely the phosphate content of a soil, but its mineral fertility as a whole (the percentage base saturation) which indicates the probability of its response to phosphate. Recently Birch has found a relationship between the citric-soluble silica in the soil and the effect of added phosphate, but the meaning of this is not yet clear. While it is too much to hope that soil analysis will become the only necessary indicator, this chemical study of plant and soil helps to explain, in some places at least, the effect of phosphate on crop yield.

As a result of many years' experience of the soils of the Kenya Highlands, Gethin Jones has been able to name and describe some of the soils on which the effect of phosphate on wheat has been tested in field trials. Robinson could then find, by statistical analysis, the probability of profitable cash returns on each soil type, using imported or locally produced phosphatic fertilizers at different rates of application. While his findings must be taken as indications rather than firm forecasts, he has introduced the factor which interests the farmer more than any other, namely the profit and loss account in fertilizer applications. But environmental factors, such as drainage and rainfall, may be of overall importance, and the results of field trials must be used in conjunction with local knowledge of field or farm.

In his paper, Doughty concludes that the more acid, highly leached, highly coloured soils give responses to phosphates, whereas the pallid soils, which are common in Uganda, do not normally react as well. This generalization is by no mean straightforward, since other factors, as yet unexplained, may affect the response. For instance, in the Kenya Highlands Fertilizer Scheme, which is reported on by Holme and Sherwood, at least one area was noticed in which something prevented the higher yield which was indicated by observation of the crop in its earlier stages. It is known in other parts of the world as well that a fertilizer treatment may have a very obvious effect on the early growth of a crop and give every indication of a definite response, but in the end the harvest yields show little difference between control and treated plots. Crowther has found that zinc deficiency may sometimes be the cause of such anomalous results with phosphate, since phosphate makes soil zinc less soluble, and thus might accentuate a tendency to deficiency of zinc: the influence on phosphate response of zinc, copper, and other minor elements is now being studied in East Africa.

The residual effects of phosphate are important in East Africa, where transport charges and losses in transit through rough handling are high. There is sufficient evidence to suggest that residual effects are frequent but not general, and work is in progress on indirect manuring of the crop by applying phosphate to the grass ley. Experience in Great Britain during the war showed the importance of applying phosphate to grass or to the first crop after ploughing up the ley. This is now being investigated in East Africa, and Dougall reports that applications of phosphate to natural and established pastures, and to the seed bed of newly sown leys, increase the yield per acre of dry matter, protein, lime, phosphorus and carotene. The main effect of phosphate on newly sown leys is to promote their establishment: on permanent grassland a relationship was found between pH and phosphate response, the more acid soils giving greater responses than those which were near neutrality. A relationship was also found between phosphate response and rainfall on newly sown leys, and it appears that in this respect the latter are more dependent on rainfall than are permanent pastures.

In East Africa it has frequently been observed that the first crop after breaking up a grass ley is not as good as the second crop, and although it seems likely that nitrogen should be required to break down the organic matter, this has not been found to be the case. Phosphate may be required at this stage, with or without nitrogen, but evidence on this point is too scanty for generalization. In view of these observations on planted grass leys, it is of interest to note that Peat, working on hill sands in the Lake Province of Tanganyika, records considerable increases in yields of cotton and bulrush millet following a three-year tumbledown fallow which consisted predominantly of the composite weed *Tridax repens*. This fallow had an unimpressive and sparse appearance, but the increases were large (up to 70 per cent) and definite, and it has been suggested that the *Tridax* may have made phosphate available to the succeeding crops.

Of the crops studied, wheat seems to give the most clear-cut responses to phosphate. Amongst other food crops, sorghum responds better than maize, and maize better than finger millet; sweet potatoes have given very little response. In Zanzibar, applications of phosphate to pineapples did not give positive responses and even tended to decrease yield, but on one soil type (*changa*) as much as 100 per cent increase in the yield of maize, and nearly 300 per cent increase in sunflower yield, were obtained from 2 cwt. single superphosphate per acre, while 3 cwt. caused a 200 per cent increase with rice. In field trials carried out by the Overseas Food Corporation, groundnuts responded to phosphate in all areas, the average increase in yield being about 100 lb. kernels per acre with a dressing of 0.5 cwt. P_2O_5: some evidence was obtained that half this dressing would be nearly as effective. In

sisal trials, phosphate has not so far caused increases in yield of fibre, but experiments have recently been planted on exhausted land, and the results of these may reopen the question. There is some evidence that phosphate produces a broader sisal leaf, and that it reduces chlorotic mottling; on certain soil types it is useful in establishing young sisal. With pyrethrum, 300 lb. per acre double superphosphate, placed at the base of the ridge before planting, gave striking responses in the Southern Highlands of Tanganyika, but in Kenya, even where phosphate has been effective, it merely caused a short-lived increase in flower production during the first season only.

Of the perennial crops, tea has given significant and immediate responses to phosphate in Ceylon, but experiments in East Africa have not yet reached the stage where conclusions can be drawn on the effect of phosphate, and all that can be said at present is that phosphate is well worth investigation. Coffee did not respond to added phosphate by giving increased yields, although evidence was obtained that the plant had absorbed additional phosphate. When phosphate was applied with organic manure, the two were mixed in order to reduce the possibility of fixation by the red lateritic soil, but even this did not produce significant increases in yield.

Nitrogen

In his paper Glover summarizes his physiological studies of the mineral nutrition of maize and sorghum, and he found that the interaction between nitrogen and phosphorus was most marked. They had to be supplied in suitable amounts to balance one another, otherwise growth was inefficient: for example, if nitrogen limited growth no amount of additional phosphorus would make the plant grow larger, and likewise, if phosphorus limited growth no amount of additional nitrogen would make it grow any larger. The state of balance between nitrogen and phosphorus can be established at many different levels of supply, but of course the highest suitable level produces the largest plant. At this high level the highest and earliest yields of grain were obtained, but it was found that slightly less well-nourished plants, which were slow in maturing, could produce yields nearly as high as those of better-fed plants, because of a longer period of uptake of nitrogen. It is important to note that these less well-fed plants were not stunted although they grew more slowly.

Since nitrogen, more than any other fertilizer, stimulates vegetative growth, a deficiency of any other nutrient may be accentuated by applications of nitrogenous fertilizers, and the response to nitrogen is complicated by this fact. Increased yields obtained by applying nitrogen may disturb the balance of other elements, such as potash or magnesium, to a point were deficiency diseases become obvious, but symptomless deficiencies, particularly of minor elements, may also limit growth if yields are raised year after year by nitrogen applications.

The interaction between nitrogen and phosphate is shown in Le Mare's paper on the work of the Overseas Food Corporation. With both maize and groundnuts nitrogen and phosphate together gave much better responses than did either alone, the most effective treatment of those tested being 0.4 cwt. nitrogen as sulphate of ammonia plus 0.5 cwt. P_2O_5 as triple or single superphosphate. Doughty found that, with maize, sorghum and millet, the effect of added nitrogen was greater on pallid-coloured soils, on which phosphate gave little response as compared with the highly coloured soils, which give definite responses to phosphate. On the average, maize and finger millet responded to sulphate of ammonia, but the increase in yield was not always significant or economic. With sufficient rain, time and method of application did not seem to be important. Holme and Sherwood, on the other hand, found that the application of nitrogen to maize at tasseling had the most consistently beneficial effect, and they suggested that ½ to 1 cwt. sulphate of ammonia both at planting and at tasseling would be an economic dressing on many soils. From Uganda, Mills reports striking responses of maize to sulphate of ammonia, one field trial giving 66 per cent increase with 2 cwt. sulphate of ammonia, while 4 cwt. gave 97 per cent increase. In another experiment, where the control yield of maize was 3,400 lb. per acre, a 50 per cent increase was caused by 2 cwt. sulphate of ammonia. In Zanzibar most soils respond to nitrogen, increases in maize yield as high as 80 per cent being given by 1 cwt. sulphate of ammonia per acre. Sorghum has also given marked responses in Zanzibar, a 50 per cent increase with 1 cwt. and 200 per cent increase with 3 cwt. sulphate of ammonia: rice has given even greater responses, a fivefold increase due to sulphate of ammonia being on record from Pemba Island.

In the Kenya Highlands, wheat did not give worthwhile increases in yield with sulphate of ammonia: responses have been obtained with maize but it seems possible that some other factor is limiting growth and yield, and this requires further study. Pineapples in Zanzibar give good responses to nitrogen, both the number and size of fruit being increased during the first two seasons, but the strain of heavy bearing resulted in fewer fruit in the third season, although their average size was maintained.

It was found in Uganda that cotton benefited from the application of 2 cwt. sulphate of ammonia at flowering, but the increase in yield was not always sufficient for an economic return. In that area the action of nitrogenous fertilizers is obscured by a build-up of soil nitrate during fallow or resting periods, and investigations are now being carried out on the nitrogen cycle in the soil: these are discussed below in the section dealing with nitrate accumulation in soil. In the Lake Province of Tanganyika, where cotton is rotated with bulrush millet, a top dressing of nitrogen following the application of organic manure raised the yield in the year of application only, and it is interesting to note that even a definite economic increase of this kind would not attract African peasant farmers, since the risk of crop failure through drought and other causes would make them hesitate to put actual cash into the crop.

In Kenya, sulphate of ammonia increased the yield and the feeding value both on grass leys and on established pastures, the recommended dressing being 1½ cwt. per acre sulphate of ammonia at sowing or 1–1½ cwt. as a top dressing on established grass. While it is well known that repeated applications of sulphate of ammonia may increase soil acidity to a dangerous level, it is surprising to find that, in the short period of two years, Dougall obtained significant increases in soil acidity which were directly related to the amount of nitrogen applied, under both permanent pasture and newly sown leys. Further work on this point is in progress, as it is of great importance in grassland improvement in the Kenya Highlands.

This work of the pasture research section of the Kenya Department of Agriculture has been in progress for only two years, and recommendations to farmers are still tentative, but it seems clear that considerable increases in grass yield can be obtained by suitable fertilizer applications. A noteworthy point in this connexion is that an increase in the carrying capacity of a pasture may accentuate the lack of food during the dry season, and work is in progress on extending the growing season and on silage and other methods of preserving bulk feeds. Both in Kenya and in Tanganyika, pyrethrum gave uneconomic responses to nitrogen, and in several trials it delayed flowering or decreased the final yield significantly. This is theoretically reasonable, since nitrogen stimulates vegetative growth whereas it is only the reproductive part of the plant which is harvested with pyrethrum. With tea, on the other hand, only the vegetative part of the plant is harvested, and it is therefore not surprising that nitrogen is the most widely used fertilizer. Sulphate of ammonia seems to be preferable to all other nitrogenous fertilizers in tea culture, partly, at least, owing to its acidifying effect on the soil, since tea will not grow well when the soil is less acid than pH 6.2. With sisal, as with tea, the leaf is harvested, but the sisal grower is concerned primarily with the yield and strength of the fibre. So far in East Africa economic increases in yield of fibre have not resulted from applications of nitrogen. Growth records have indicated that nitrogen hastens the growth of the sisal plant, but where there is too much of it the leaves tend to be long and flaccid and the fibre may be finer. Since sisal is a succulent its nitrogen economy may be different from that of other vegetative crops, but there is also a possibility that experiments now being carried out on exhausted sisal land may show better responses to nitrogen.

Potash

In most parts of East Africa no significant responses to potash were obtained with maize, sorghum and millet, but on the coastal belt of Tanganyika there were important potash effects on maize and sorghum in the second and third seasons. In the Western Usambaras one experiment showed a very marked response to potash, and in a second season the addition of potash gave a stand of maize whereas without potash no plants survived. On one of the Zanzibar soil types (*kinongo*) potash has occasionally given excellent responses on maize and sorghum and there is strong evidence that potash assists cereals to grow away from borer attack.

Significant responses to potash on wheat are recorded from the Southern Highlands of

Tanganyika, and potash combined with phosphate gave marked increases in yield. The highest yield of all was given in that area by 21 lb. N, 50 lb. P_2O_5 and 50 lb. K_2O but the cost of treatment is high (£5–£8 per acre) owing to the long road haul from the nearest railhead, and the expenditure may not be worth while in view of the risk of crop failures due to drought, rust, and other causes. In the Kenya Highlands, in 1948, there was an average overall increase of only 100 lb. per acre on wheat caused by 0.46 cwt. muriate of potash, the response being positive in 25 experiments out of 30 and significant in 13 of these. In 1949 and 1950, however, the responses to potash were negligible, and it is possible that this transitory effect was due to the particular seasonal conditions in the first year. In these wheat experiments it was observed that, even if potash did not affect the yield, it produced a noticeably plump grain.

Both in Kenya and Tanganyika, potash had no definite effects on the yield of pyrethrum, but there is some evidence that 50 lb. per acre of muriate of potash slightly increased the pyrethrin content. It was thought at one time that lack of potash might be connected with the incidence of Ramularia bud disease, but no conclusions on this point can yet be drawn. Tobacco experiments in the Southern Highlands of Tanganyika showed increases in yield which were directly dependent on the amount of potash applied, up to 48 lb. K_2O, and the highest yields were given by 30 lb. P_2O_5, 48 lb. K_2O, and 24 or 48 lb. N, this dressing giving over 78 per cent of high-grade leaf.

Healthy sisal does not appear to respond to potash in Tanganyika and it has been noticed that excess potash results in acute chlorotic mottling even if lime and phosphate are present. These observations are curious in view of the fact that Banding disease, which is prevalent in parts of Tanganyika, is primarily due to potash deficiency and several estates are now applying potash as a routine. It has been suggested that the soil K/N ratio is an important factor in controlling the uptake of potassium by plants, and that a K/N ratio of 0.05 is critical.

Coffee gives no response to potash in East Africa, and on the whole most tea soils are well supplied with potash. But the tea crop drains the potash reserves, since the K_2O content of the tea "flush" may be as high as 2.5 per cent. In Ceylon, there was no sign of response to potash in field experiments for the first 11 years, but since then there has been evidence of progressively increasing potash deficiency that has affected every part of the plant and has led to defoliation and eventual death of the bushes.

Calcium

Liming affects a soil in two ways, by reducing soil acidity, which may affect the availability of elements other than calcium, and by providing more calcium for the nutrition of the plant. In liming to reduce acidity, it is important that the lime should be finely ground and that it should be thoroughly mixed with the soil, but in liming to correct calcium deficiency it is often better to use coarsely ground limestone in order that the plant may have more chance of taking up the calcium before it is adsorbed into the clay fraction of the soil.

In the nutrition of the grain crops, it is seldom, if ever, that acute calcium deficiency is the limiting factor, and, although Glover has found in his physiological studies of maize that a very low supply of calcium causes the roots to be soft and gelatinous, it is possible that he was using lower concentrations of calcium than is normally found even in acid soils. Yet this observation suggests that inadequate calcium may have an adverse effect on plant growth without producing visible symptoms.

Holme and Sherwood record effects from lime only on occasional very acid soils, with some residual effect when a response was obtained, and they suggest that, for wheat, pH5 seems to be the critical level of soil acidity, below which lime may benefit the crop. Their results did not indicate critical pH levels for other crops, but it is interesting to note that Kroll, in his pyrethrum trials, had only one increase in yield through liming, on part of an experiment where the pH of the soil was 4.9, while no effect was noticed on the remainder of the trial, where the soil pH was 5.2. From his experience of Kenya soils, Gethin Jones suggests that responses to lime are unlikely when the soil pH is over 5.2, but even below that figure there may be no response. Ground limestone is so expensive in Kenya that the cost of heavy liming could be equal to the value of the land, so considerable care is necessary in deciding on which soils to apply lime.

On food crops in Tanganyika—maize, wheat, sorghum, and groundnuts—liming has been

found to be ineffective, and experiments in Uganda have also indicated that paying responses from lime are unlikely in that country. The fact that in the United States, groundnuts produce empty shells through lack of calcium, prompted the Scientific Department of the Overseas Food Corporation to lay down trials with ground limestone and gypsum applied at different times and at different levels, but no effect of the added calcium was observed.

On the other hand, liming has shown beneficial effects on the more acid soils of Zanzibar, and by bringing the soil to pH 6.5 responses to lime have been obtained with sweet potatoes and rice. But the reaction is not clear, since reduced yields after liming have been just as frequent as positive responses, possibly by inducing minor element deficiencies.

Calcium deficiency can be caused by excessive manganese uptake, and some evidence of this has been found in coffee at Mbosi in the Southern Highlands of Tanganyika. Apart from this, no results are reported in which coffee has reacted to liming, and the tea plant is so sensitive to a soil reaction above pH 6.2 that lime is never applied on tea estates.

Sisal is a gross calcium feeder and continuous sisal-growing on red earths leads to progressive acidification of the soil. It is not yet known how far calcium affects the yield of fibre or its quality, but it has been observed that it improves leaf colour. It is sometimes stated that plants grown on soil which is low in calcium tend to be more susceptible to bole rot, but a definite association between the two has not yet been confirmed. Chlorotic mottling of sisal is reduced by applications of limestone and it seems possible that this disease is related to excessive uptake of minor elements: excess cobalt has been reported in leaves showing chlorotic mottling. In the same way the symptoms of Purple Leaf Tip Roll tend to become milder with increasing amounts of lime, but spectrographic analysis showed high calcium percentages in leaves of plants suffering from this disease. Whatever the explanation of these observations, it is clear that the calcium nutrition of sisal is of great importance, and small but significant responses on healthy sisal have been obtained by applying about 2½ tons ground limestone per acre before planting. Maintenance of the calcium status of the soil may be a key factor in continuous sisal-growing, and it is possible that rotating sisal with elephant grass may help to maintain the calcium status by means of its deep root system, which brings up nutrients from the subsoil.

Organic Manures and Mulches

Cattle manure and compost have immediate and residual effects which have not yet been explained, and it seems probable that an organic manure fortified with chemical fertilizers would be the best method of maintaining or raising soil fertility. Tractor-drawn manure spreaders are being used to some extent on European farms in East Africa, and the ox-drawn equivalent might well be tried by the more progressive African farmers. In his fertilizer trials on African food crops, Doughty found that all crops responded better to cattle manure than to fertilizers; in one trial only was nitrogen and phosphate as effective as the equivalent dressing of cattle manure. Bellis records that studies of the nutrient requirements of the relatively thinly populated upper Kikuyu bracken lands, the soils of which are highly leached, have indicated a particular effectiveness of light dressings of cattle manure and a relative ineffectiveness of major fertilizers.

In the Southern Highlands of Tanganyika, Gunn found that, in general, farmyard manure proved to be the most valuable single fertilizer for wheat, and when it was supplemented by phosphate and nitrogen further increases in yield were obtained. Owing to the excessive cost of fertilizers in the southern part of this area, the only practical recommendation is that farmyard manure should be applied at about five tons per acre, but it is possible that even there small quantities of phosphate added to the organic manure might be profitable. In the Western Province of Tanganyika, Le Mare found that cattle manure at ten tons per acre gave a mean increase of 380 lb. per acre in the yield of maize, but nitrogen and phosphate together increased the yield by 450 lb. in the presence or absence of organic manure. In the next year the residual effect of cattle manure increased the groundnut crop which followed the maize by 200 lb. kernels per acre. In Zanzibar two of the soils (*namo* and *changa*) have given responses with compost, yams in particular giving very greatly increased yields.

The most striking results with cattle manure are described by Peat who found that, on hill sands in the Lake Province of Tanganyika, the residual effects of dressings of organic matter at three or seven tons per acre persisted for eight years on cotton rotated with bulrush

millet. Equivalent amounts of nitrogen and phosphate gave results similar to, or greater than, these organic dressings, but only in the year of application. In temperate climates the effects of farmyard manure are physical, chemical, and biological, since the amount of organic matter in the soil only slowly decreases. The moisture relationships of the soil are improved, plant foods are adsorbed and retained in a form in which they are readily available to the plant, and the micro-biological activity is maintained. In the tropics, however, the actual organic material of cattle manure disappears after a very short time, and the residual effects of a single dressing of seven tons per acre cannot be physical or biological eight years after its application. So far, no explanation of this long residual effect has been found, and although the evidence points to the influence of minor elements, the problem requires much further study.

With pyrethrum, no increases have been obtained with cattle manure applied directly to the crop in Kenya, in fact there were indications that organic dressings may depress flower production. It is possible, however, that pyrethrum might benefit by applying cattle manure to other crops in the rotation, and this point is now under investigation. When 60 lb. triple superphosphate plus ten tons compost was applied, the yield was not raised in the first season but was appreciably increased in the second and third seasons, the total effect over three years being an increase of 500 lb. dry flowers per acre. In Tanganyika one trial with five tons compost per acre gave a significant increase of 127 lb. per acre over two years; ten tons per acre did not give further increases. But on another farm there was no response to organic manure, and on the whole there were no very profitable responses to compost on pyrethrum.

The effect on coffee of organic manures and mulches has been studied both in Kenya and in Tanganyika, and the conclusion has been drawn that applications of compost or cattle manure are not likely to be profitable, but mulching gives very good returns. Pereira studied the moisture relationships of mulched and unmulched soil under coffee, and found that the effect of mulching was far greater in assisting the penetration of rain than in impeding evaporation during the dry season. For this reason he advises that grass mulch should be applied at the onset of the rainy season, and by doing so he found that the yield in a dry year was increased by 100 per cent, while in a year of good rainfall the increase was 75 per cent. Since it would require nearly two acres of grass to produce mulch for one acre of coffee, Pereira advises that fertilizers and organic manures should be applied to grass rather than to coffee, with the object of applying plant nutrients through the mulch and of reducing the acreage of grass required on the estate.

In the Northern Province of Tanganyika, Sanders did obtain a 22 per cent increase in yield of coffee when 40 lb. compost per tree was applied, but banana trash mulch at the same rate per tree gave him a 50 per cent increase over a ten-year period. Of the mulches tested, elephant grass, guinea grass and banana trash, the latter was the most effective, and it is of interest to note that a double dressing (80 lb. per tree) was no more effective than a single dressing, although the 40-lb. application had rotted away by the middle of the dry season and left the soil uncovered till the next rains. Pereira examined the soil under mulch to see why it should cause better rain penetration, and found that mulching is a most effective method of cultivation, judging by the number of holes caused by soil organisms.

Organic manuring in tea cultivation was stimulated during the war by the severe shortage of fertilizers and by the writings of the late Sir Albert Howard. In his paper, Eden describes an experimental area of young tea in Ceylon to which Adco compost was applied in four successive years at the rate of 15 tons per acre, providing in all 540 lb. of nitrogen. Subsequently, single (40 lb.) and double doses of nitrogen were superimposed on compost and control treatments. The effects of the organic manure were still seen 12 years later, and the efficiency of the nitrogen dressings were much greater when applied to the compost than when applied alone.

As a result of his sisal trials, Lock concludes that the rate of depletion of plant nutrients from the soil could be lessened if all sisal waste could be returned to the land, but he appreciates that on most sisal estates the practical difficulties could not be overcome. In this connexion, an article by den Doop in the East African Agricultural Journal (July, 1949, p. 15) is worthy of notice, as he deals with the question at some length. In view of the practical difficulties in returning sisal waste to the fields, Lock has tested its effect on bulbil nurseries, as these could be sited near the

factory. Trials have shown consistently that 50 tons per hectare of either fresh or old sisal waste doubles or trebles the size of the plants with suitable spacing, and a greater effect still is obtained if the application is increased to 100 tons per hectare. On sisal plants one year old, fresh sisal waste at 400 tons per hectare is showing a definite improvement in growth, and the solid material extracted from 400 tons of leaf is also showing a similar effect.

Nitrate Accumulation in Soil

Investigation of nitrate accumulation in Uganda soils was first carried out by Griffith and Manning, who found that high nitrate accumulation (up to 200 p.p.m. NO_3) may occur in bare fallow soil, very little (less than 10 p.p.m.) in shaded or mulched soil, and something in between these figures on cropped soil. Later studies, which are summarized by Mills, have confirmed these findings, and a new point of interest is being studied in the effect of nitrogenous fertilizers on the nitrate status of the soil.

Applications of sulphate of ammonia cause the nitrate content of a soil to be raised both to a higher level and for a longer duration than an equivalent dressing of nitrate of soda. This is due to the adsorption of ammonium ions by the soil colloids, thus protecting them from leaching. The action of farmyard manure is similar to that of sulphate of ammonia, but the nitrate content does not reach such high levels. Limestone, although it reduces soil acidity, does not cause an appreciable increase in soil nitrate.

The original nitrate studies were made on the top six inches of soil, but the lower layers have now been examined. In the top inch a figure in excess of 300 p.p.m. NO_3 may be obtained, with a sharp drop to 40–60 p.p.m. in the second inch, and this latter nitrate content persists to about nine inches, when there is a gradual rise. These figures refer to bare fallow soil; under shade a typical result is 50 p.p.m. in the top inch dropping to 20 p.p.m. in the second inch. Rain washes the nitrate in the surface down into lower layers, and there is, temporarily, a lower nitrate content in the surface soil with correspondingly more nitrate in the sub-surface layers. Nitrate is again produced in the surface soil when it dries, and this may possibly become "fixed" in some way. The nitrate in the lower layers may be converted into other forms of nitrogen or may diffuse in the soil moisture either up or down.

On following the movement of nitrate down the soil profile it was found that in bare fallow soil, an accumulation of nitrate amounting to more than 400 p.p.m. was found at a depth of about three feet, the actual depth varying according to the conditions. This subsoil accumulation was less with shaded soil; under mulch there was a gradual increase to about 100–150 p.p.m. NO_3 at six feet, and it is possible that the true peak may have occurred even lower down. Under crops the nitrate accumulation was less than with bare fallow or shade, but a peak was found at a depth of four to five feet.

The effects of different crops on the nitrate content of surface soil was also studied in this experiment. Millet, maize and sunnhemp all reduced the nitrate content, which did not increase during growth of the crop, but cotton allowed a build-up of nitrate in its early growth, and this dropped at the peak of flowering and then rose again. After three years' resting under leys of elephant grass, chloris and paspalum, the nitrate content of the whole profile down to six feet was found to be almost nil, but after opening up the ley, nitrate accumulated in the surface horizons at rates which varied with the species of grass; paspalum very slowly with low nitrate for a long time, elephant grass more rapidly to a higher peak, and chloris intermediate.

When Dr. Jane Meiklejohn examined these experimental results from the standpoint of soil microbiology, she found that they would not fit into the usual pattern, since the conditions under which there was the greatest accumulation of nitrate (bare fallow) were not those normally associated with high microbiological activity. One possible explanation suggested by her is that, on the unshaded plots where the temperature is highest, the nitrifying bacteria are heat-resistant while the denitrifiers are not, thus favouring a higher nitrate content than the shaded soil even though no more actual nitrate was produced.

Laboratory tests on heat-tolerance did not support this theory and further work is required to solve the problem, but meanwhile three suggestions have been put forward by Dr. Meiklejohn. In the first place it is possible that these soils contain nitrifying bacteria which do not grow under the laboratory conditions which have been tried; this point is being further investigated. Secondly, it is possible that the nitrifying population of the soil has radically altered since the experiment

was begun, and this suggestion is supported by the fact that the greatest accumulations of nitrate were found in the first season of the experiment (1949/50). The third theory is that nitrification in these soils may not be a biological process, but may be a photo-chemical reaction catalysed by various metallic oxides, and the fact that these soils have a very high content of exchangeable manganese may have a bearing on this suggestion.

Minor Elements

In East Africa, deficiencies and excesses of minor elements in crop plants have been suspected for some time, but the evidence is mainly that of observations, since facilities for spectrographic estimation of minor elements such as copper, cobalt, and zinc have only recently become available. A few plant samples have been sent to the United Kingdom for estimation of these elements, but their number was too small to permit proof or firm conclusions. Yet the evidence, scanty though it is, does show that research on the subject will be well worth while and might explain why fertilizer applications in some places, which should have been effective according to theory, have not produced positive responses.

It has been shown in other countries that a deficiency of zinc is aggravated by applications of phosphate, since the action of the latter is to make zinc less soluble and therefore to reduce its uptake by plants. It was suggested that a deficiency of copper, not zinc, may be responsible for lack of response of wheat to phosphates in some parts of the Kenya Highlands, and in observation tests an improvement in the health of the plants, estimated to be about 10 per cent, did occur after spraying with a copper solution. A much more marked improvement would be expected if copper is the limiting factor, and yet spectographic analyses carried out in England have indicated that Kenya wheat may be low in copper. In Uganda the treatment of cotton seed with a copper dressing against "Black Arm" disease may benefit the plant in some way additional to its bacteriological action, and coffee on the Kikuyu red loam in Kenya does respond to copper sprays in addition to their fungicidal value. In fact it has been observed in Kenya that the tonic effects on coffee leaves of copper sprays are similar in many respects to the effects of mulching, in that the leaves are larger, thicker and greener with less tendency to yellowing, they stay on the tree longer, and the unevenness of crop production, with terminal dieback after peak crops, is lessened.

With tea the importance of copper lies in the fact that the enzyme which causes fermentation during processing contains copper in its molecular structure, and in Ceylon it was found that one apparently healthy tea bush produced leaves which would not ferment at all. There are as yet no signs of lack of enzyme activity in tea from the Kericho area of Kenya, but research on the copper relationships of crops and stock in Kenya would be watched with interest by the tea research team.

Sulphur deficiency in crops plants is uncommon, except for the striking "tea yellows" in Nyasaland which were found to be due to lack of sulphur, but a recent observation by the Fisheries Research Organization that the waters of Lake Victoria are abnormally low in sulphur has reopened interest in that element. Yet sulphate of ammonia is the normal and effective treatment for sulphur deficiency, and if the vast area draining into Lake Victoria were deficient in sulphur one would have expected very striking results in those fertilizer trials in which nitrogen was applied as sulphate of ammonia.

There is a wide variation in the tolerance of individual species for deficiencies and excesses of minor elements. For example, lucerne can grow on soils which are low in zinc, whereas red clover is highly sensitive to zinc deficiency. Edible lupins seem to take up large quantities of manganese and still grow normally, whereas other plants may suffer from calcium deficiency if there is too much available manganese in the soil. Thus each crop plant must be studied in relation to its requirements for minor elements before general conclusions can be drawn on the need for these in East African agriculture.

SUMMARIES OF PAPERS

The History of Artificial Fertilizers in the European Highlands of Kenya, with Special Reference to Sodaphosphate

G. H. Gethin Jones, E.A.A.F.R.O.

During the years before the war there was a growing realization of the need of better farming methods with increased yields per acre. This involved the adoption of some soil conservation measures, the starting of mixed husbandry and a small but increasing use of artificial fertilizers, mainly phosphates applied

to wheat. Some bone meal was given to high-yielding, old-established coffee lands in the Thika and Kiambu districts. No artificial fertilizers and indeed very little organic manure were used in African areas.

The increasing use of phosphatic fertilizers on cereals, and on wheat in particular, was based on the frequent good response shown by simple field experiments on many of the main wheat-growing soils. There were many instances of relatively small dressings of 80 to 100 lb. per acre of double supers, applied with the seed-drill to long-cultivated wheat lands, resulting in greatly increased yields which made possible continued war-time wheat production on such lands. It happens that the elevated regions which are climatically the most suitable for wheat have the most leached and highly unsaturated soils, which are very deficient in "available" phosphate, and these generally gave good responses in farmers' strip trials: placement of the fertilizer was found to be essential.

War-time food-production demands increased the need for phosphatic fertilizers at a time when the importation of superphosphates was severely restricted. Seychelles phosphate was imported in greater amounts; the collecting and grinding of animal bones from the game reserves and African settled areas made available over 1,000 tons of bonemeal per annum; more than 4,000 tons of cotton seed ash were obtained from Uganda, and local scattered supplies of bat guano were exploited wherever possible. With very limited importations of double superphosphates, the supply of phosphatic fertilizers did not meet the growing demand. Steps were therefore taken to exploit the deposit of a primary phosphate which was known to occur along the eastern border of Uganda. It was proved that there are vast reserves of readily mined ore carrying 8 per cent to 35 per cent phosphoric oxide, with a working average of 25 per cent, mainly in the form of fine-grained francolite.

The true manurial value of ground rock phosphate from Uganda was tested by chemical analyses, by a pot culture technique, and by a few field experiments. The results indicated that only about half as much "early available" phosphate was liberated from it as compared with other commercially worked rock phosphate deposits, and it became apparent that the Uganda phosphate rock was not suitable for application by itself to annual crops.

Sodaphosphate

In the search for a method of processing by which the phosphate in the raw rock could be made more available to plants, the obvious preference lay in calcination with crude sodium carbonate from Lake Magadi, and a suitable method was worked out, first in the laboratory and then in a pilot plant. In laboratory studies the new sodaphosphate showed great promise. Though it has very little "water-soluble" phosphate, it does contain a high proportion of "citric-soluble" phosphate, the amount depending mainly on the proportion of ingredients used and the temperature and length of heating. Eventually it was found that 80 per cent to 90 per cent of the total phosphate could be economically converted into the citric-soluble form.

Pot culture trials showed that cereal seedlings could absorb roughly five times as much phosphate from sodaphosphate as from raw Uganda rock phosphate, using the same dressings. Comparative tests with other phosphatic fertilizers such as Seychelles phosphate and bonemeal, showed that sodaphosphate was more available to plants. It was found to be almost as effective as the phosphate in materials of the superphosphate class, provided that it was mixed in the soil within the placement zone.

During the war it was not feasible to carry out long-scale field experiments, but in 1945 the Kenya Department of Agriculture was able to arrange for a few field trials, using sodaphosphate prepared in the pilot plant of the East African Industrial Research Board: these trials gave fair to very good responses in different lands, thus tending to confirm the indications given by the earlier pot culture trials.

The demand for the new local processed phosphate was immediate and large, but there remained certain technical difficulties in large-scale calcination in a rotary kiln which delayed the building of a suitable plant for commercial production. Meanwhile a method of small-scale calcination on the farm was worked out and used by several farmers to produce a rather crude product of varying composition. Most of the technical difficulties in large-scale production have since been overcome and two commercially owned plants are now in operation.

At this stage the whole problem of fertilizer requirements was placed on an East African basis. A fertilizer scheme staffed by the East

African Agriculture and Forestry Research Organization and wholly financed by Colonial Development and Welfare funds was inaugurated. It worked in close association with the territories, and conducted an extensive three-year programme (subsequently extended to a fourth year) on a wide variety of soils in the African reserves, especially in the densely populated areas around Lake Victoria. The Kenya Government inaugurated and financed a parallel programme of experiments in the Kenya Highlands under a team led by an I.C.I. officer. The two schemes worked in the closest co-operation throughout. Their results are reported in separate papers.

The Value of Fertilizers in African Agriculture Field Experiments in East Africa, 1947–1951

L. R. Doughty, E.A.A.F.R.O.

Over the period 1947–1951 fertilizer experiments were carried out fairly extensively in African areas bordering Lake Victoria and in the northern coastal belt of Tanganyika. Numerous exploratory experiments using sulphate of ammonia and triple superphosphate in simple factorial combination were undertaken, and, in areas where fertilizer responses were recorded, more elaborate experiments involving various combinations of levels, forms and methods of applying phosphate, levels and times of applying sulphate of ammonia and potash and dung were undertaken, the experiments in some instances being carried on for two or three years on the same sites. The potash studies were confined to Tanganyika and the detailed nitrogen studies to Uganda. The crops used were the landholder's choice and were mainly cereals. The experiments were undertaken only during the main rains each year. Plot size ranged from 1/40th to 1/120th acre, 1/80th acre being the minimum preferred: large plot sizes were found to be particularly desirable when the experiment was carried on for a number of years. Fresh head weights were taken in all trials harvested, the results being connected to dry grain weights by samples from each experiment. Owing to the mosaic of African cultivation on which the trials had to be imposed and to the inadequacy of supervision which was possible, a proportion of the experiments failed, others were only partially successful, and the error factor was high. In areas where rainfall was inadequate or soils excessively open-textured, drought was sometimes severely damaging, pests, diseases and vermin were particularly troublesome, catching the rain for planting (which was essential for success of an experiment) was peculiarly difficult, and failures and errors were consequently particularly high.

To the north-east of Lake Victoria, moisture availability during the growing season was adequate. Here on volcanic soils and on deep, stable, mature granite soils such as occur in the south-east of the Eastern Province of Uganda and nearby in the north-west of Nyanza Province, the response of maize, sorghum and finger millet to sulphate of ammonia was general. The responses of maize and finger millet promised to be economic but the economy of the sorghum response was less certain. The biggest yield increases were obtained with application of sulphate of ammonia of up to 0.95 cwt./acre sulphate of ammonia, or 0.2 cwt./acre N: further increase in the rate of its application only exceptionally gave marked further yield increases. Time of applying sulphate of ammonia was unimportant at least during the period of vegetative growth. Broadcast application was effective provided rain fell reasonably soon after fertilizing.

Phosphate sometimes exerted beneficial effects on early growth but these generally disappeared before harvest.

On soils of the basement complex such as occur in north-eastern Nyanza Province, response of maize, the only crop tested, both to phosphate and sulphate of ammonia was high and economic.

On laterized, deeply dissected granite soils and on ancient sediments such as occur in and immediately south of the Nzoia Valley, response to phosphate is of major and economic importance. Nitrogen effects are smaller and are frequently sub-economic. *Boma* manure effects also are small.

Where phosphates are generally effective—

(1) repeated applications of triple superphosphate have a pronounced accumulative effect;

(2) the superphosphates are about 5 per cent more effective than sodaphosphate;

(3) Uganda rock phosphate has a valuable effectiveness: in most experiments where benefits from its use have been recorded the benefits have become apparent only after the second or third

season's application. Uganda rock phosphate was most effective in the area south of the Nzoia Valley;

(4) in terms of crop, sorghum responds better than maize, maize better than finger millet, and sweet potatoes very little, to phosphate;

(5) the optimum rate of phosphate application seems to be around the equivalent of 1 cwt. triple superphosphate per acre, particularly if the dressing is given annually for a few years. At the same time broadcasting has been found as effective as placement at a rate of application as low as 0.48 cwt. triple superphosphate per acre and this has been taken as indicating that even lower rates than this may be effective provided that the fertilizer is placed.

A rough estimate gave the potential phosphate consumption for the responding areas north-east of Lake Victoria as initially the equivalent of 5,000–7,500 tons per annum triple superphosphate, though in course of time this high level of consumption would be expected to decline somewhat: fertilization at this rate would increase crop yields by some 30 per cent. Again, provided it could be produced cheaply, a quick-acting nitrogenous fertilizer could be used beneficially each year on some 1,600–2,800 square miles of cultivation in the area.

To the south and south-east of Lake Victoria, rainfall during the growing season is variable and in some areas frequently inadequate. The information obtained here applies in main only to the lighter-textured upland soils which are the soils most extensively used for cultivation.

Responses on these soils to single applications of phosphate varied widely from place to place, from crop to crop and from year to year and frequently were apparent only during early growth, later to become less and to disappear before harvest. Repeated applications, however, led to much greater, more consistent and significant yield increases. The responses were most apparent on red loams of good depth over murram in drier areas and were least apparent on hill sands in the moister areas. The yield increases promise to be economic with cotton, but the risk of loss of crop makes the economy of applying phosphates uncertain for sorghum and millet. The superphosphates were more effective (particularly in the drier areas) than sodaphosphate, and sodaphosphate was more effective than Uganda rock phosphate.

All crops except sorghum responded to sulphate of ammonia, the response of maize in the north being the most economic. All crops responded to dung better than to fertilizer: in one instance only was an N.P. fertilizer application as effective as the equivalent dressing of dung. In the dry areas phosphates were somewhat less effective when applied in the presence of dung than when applied in its absence. Potash effects generally were small. The high efficiency of dunging associated with a consideration of the nutrient status of the soils in Lake Province, Tanganyika, suggests that increasing the productivity of the cultivated soils there is not mainly a matter of providing adequate plant nutrients.

On the coastal belt, though rainfall is usually abundant, the soils are very porous and drought is severely damaging. Nevertheless, phosphate responses particularly in the second and third cropping season were found to be fairly general on the coastal sands and on the red soils of the hinterland. Some instances, particularly in the northern part of the area, were observed of important potash effects in the second and third season. Moderate responses to dung and to nitrogen were observed.

Proposals for future work arising from these trials are:—

(1) Much more exploratory work is needed, and in areas where fertilizer responses have been established, further investigations of appropriate dosages and methods of application are required.

(2) The phosphate placement method adopted in ridge cultivation in Lake Province is believed not to be fully satisfactory and alternative methods of application (particularly broadcasting followed by ridging) need testing.

(3) The low-lying, heavy black (*Mbuga*) soils which are extensive in the cultivation steppe in Lake Province, Tanganyika, and have a high potential for mechanized cultivation, require further investigation of their phosphate status.

(4) The reason for the superiority of dung over equivalent fertilizer treatments on the cultivation steppe of Lake Province needs investigation.

expected to bring about useful increases in the yield of maize and wheat. In areas which are sufficiently well watered for green manuring to be practicable, fertilizing the green manure with less soluble forms of phosphate had as beneficial an effect on a succeeding crop of maize as did the same application of phosphate as superphosphate applied directly to the maize.

Later trials involving placement of superphosphate have demonstrated that for maximum economy of its use for wheat, this fertilizer at least should be sown with the seed in the drill.

A few trials with N.P.K. fertilizer mixtures and *boma* manure on potatoes were also undertaken, but these served merely to hold out promise for the use of a fertilizer mixture, particularly if the fertilizer mixture is rich in phosphate, and of *boma* manure as a means of increasing potato yields on some soils.

The value of phosphates having been established, the intervention of war in 1939, and with it a pressing demand for increased cereal acreage in the face of contracting stocks of recognized phosphatic fertilizers, demanded full exploration of the possibility of developing local sources of phosphates. The materials which came under particular examination were bonemeal, cotton-seed ash, and Uganda rock phosphate; and these were tested in Neubauer-type pot experiments, mainly with wheat seedlings on soil representative of major cereal-producing areas, and by simple field trials. The pot experiments established that bonemeal, cotton-seed ash, and sodaphosphate had a high early availability while Uganda rock phosphate, though having a low early availability, promised if applied sufficiently heavily and in a sufficiently fine state of subdivision also to be effective. The citric solubility of sodaphosphate was found to be a direct measure of its early availability relative to superphosphate. In the field trials, the high early availability of sodaphosphate and the low early availability of Uganda rock phosphate were confirmed whilst cotton seed, introduced direct from pot culture into general farming, was an immediate and long-standing favourite: bonemeal supplies proved inadequate for its thorough testing in the field.

The possibilities of sodaphosphate production in East Africa are great, so in view of the value which it demonstrated for itself the areas in which it was subjected to trial were expanded as quickly as the availability of supplies permitted. African areas in Central and Nyanza Provinces received particular attention. While the trials concerned suffered from the inadequacy of the supervision which was possible at many of the centres, the observations which were made gave promise of sodaphosphate, provided it could be produced cheaply, finding a wide application in Kenya. More detailed examination of the value of sodaphosphate (and of other fertilizers) was undertaken under the African and the Highlands Fertilizer Schemes. Recent fertilizer investigations connected with annual crops have continued and extended the studies undertaken under these two schemes.

In African areas, the exploratory rates of application, and placement trials initiated under the African Fertilizer Scheme, have been continued and extended to new areas in Nyanza, Central and Coast Provinces, the trials being sited with particular reference to important local soils, and the test crop used being selected mainly from important local cereals: residual as well as primary effects were measured wherever possible. Muriate of potash at rates up to 1 cwt. per acre produced no important benefits but, on some soils, sulphate of ammonia and the superphosphates at rates up to 2 cwt. per acre and *boma* manure at rates up to 10 tons per acre produced useful and, at present prices, economic returns: on other soils, no measurable effect has been obtained from applying any of these materials. Placement of phosphate has been found to have no advantage over broadcasting, even at a rate of application as low as 0.48 cwt. double superphosphate per acre and this has been taken as indicating that with placement yet lower rates of phosphate application are justifiable. Studies in the nutrient requirements of the relatively thinly populated upper Kikuyu bracken lands have indicated a particular effectiveness of light dressing of *boma* manure and a relative ineffectiveness of major fertilizers and amendments.

In European areas, Neubauer-type laboratory experiments established that, provided the fertilizer is placed below the seed, sodaphosphate and the superphosphates have a similar availability to wheat seedlings but that as the concentration of the fertilizer in the fertilized zone decreases, so the plant appears better able to use the phosphate from double superphosphate than the phosphate from sodaphosphate in producing dry matter. Further

Neubauer-type trials established for a number of soils that the early availability of the citric soluble in Seychelles phosphate depends to a limited extent on the fineness of the fertilizer. Field trials have established that even with measure of drainage, the yield and response levels of the Kinangop loam to double superphosphate are markedly lower when natural drainage is inferior than when natural drainage is normal. Long-term field trials concerned with the use of Uganda rock phosphate have been initiated. A field trial aimed at extending the applicability of the Highland Fertilizer Scheme results on wheat to barley and oats has been attempted: while detailed quantitative examination of the results is still required, the preliminary showing is that barley is relatively much more and oats less sensitive to its environment and to fertilizer treatment than wheat. Field trials not specifically involving phosphates have been concerned with the rotting-down of stubble: the crop succeeding incorporation of a large quantity of stubble has been found to benefit from sulphate of ammonia application provided the rate of application at least approaches 1 cwt. per acre, though even then the benefit is small and uneconomic at present prices.

Fertilizer and liming studies of minor importance on a miscellany of crops have also been carried out.

Proposals for the future are a continuation of present investigations, examination of means for economizing in the cost of phosphate in areas where phosphate responses have been established, examination of the relative effectiveness of different nitrogenous fertilizers and an intensification of work on liming, on suspected minor element deficiency in wheat land in Njoro and on the problem of the infertility of the upper Kikuyu bracken land.

The Effect of Fertilizers and Manures on Pyrethrum Yields

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During the past seven years a number of statistical and observational field trials with fertilizers and manures have been carried out on pyrethrum, both on the crop itself and on other crops in the rotation. Lime, mulch, compost, green manures, nitrogen, potash and phosphate as triple supers, Uganda rock, bonemeal and sodaphosphate have all been tested. While much remains to be done, the results obtained so far are of definite interest. The only increase in yield through liming was given on part of an experiment where the pH of the soil was 4.9, while no effect was noticed on the remainder of the trial where the soil pH was 5.2. In one trial, lime decreased the yield.

Mulch gave indicative results, in that when applied to young plants it tended to depress the yield, possibly by inhibiting the growth of the small splits. During the second season after planting, however, significant increases in yield were obtained with mulching; flowering continued for a longer period into the dry season, and plants seemed to weather the dry season better and to make a more vigorous start in the following year. Current trials include applications of nitrogen with mulch, in the hope that the depressing effects on younger plants will be corrected and that more clear-cut results will be obtained. No increases in yield have been obtained with farmyard manure applied directly to the pyrethrum crop; in fact, there are indications that flower production may be depressed. The possibility that farmyard manure may benefit pyrethrum when it is applied to other crops in the rotation is now being tested in a large-scale rotation experiment. No statistical results are available for compost applied by itself, but ten tons of compost plus 60 lb. triple supers per acre given over a period of three years increased the yield of pyrethrum flowers considerably in the second and third seasons. The total increase over the control plots was 500 lb. dry flowers per acre, which makes it appear likely that even this heavy dressing would be economical. As regards green manures, significantly greater yields were obtained by planting and digging in of sunflowers and lupins over a control treatment which consisted of a wheat crop.

In general, nitrogenous fertilizers seem to have had no beneficial effect, and in several trials applications of sulphate of ammonia delayed flowering or decreased the final yield significantly. Applications of muriate of potash have not given any definite effect. It was thought at one time that lack of potash might be connected with the incidence of Ramularia bud disease, but no conclusions on this point can yet be drawn. There were signs that 50 lb. per acre of muriate of potash slightly increased the pyrethrin content, but this was not confirmed in the following season.

The effect of phosphate applied in the planting holes has usually been to produce a short-lived increase in flower production during the first season only. Phosphate applied as a top dressing or drilled in between rows of established plants has not shown any effect. On the other hand, pyrethrum in the Southern Highlands of Tanganyika has responded to superphosphates placed at the base of the ridge, and it is possible that the trials in Kenya were not carried out on soils which respond markedly to phosphate applications with other crops. Another significant point is that most of the trials in Kenya were carried out with mixtures of Uganda rock and triple supers, whereas one trial, on a soil of known phosphate deficiency, where 150 lb. per acre double supers was applied, a response was obtained which continued into the second season and gave a total gain over the control of 150 lb. dry flowers per acre. One trial in which the phosphate was mainly supplied as Uganda rock gave increased yields over the first two seasons. Obviously much more work on the response to phosphate of pyrethrum is required before conclusions can be reached.

Fertilizer Experiments on Ley-establishment, Established Leys and Natural Pastures in the Kenya Highlands*

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The composition of natural pasture herbage was first studied in Kenya by Boyd-Orr [1], who considered phosphorus to be the element most deficient, and he inclined to a view that if phosphorus were supplied by fertilizers, the amount not only of phosphorus but of calcium would be increased in the pastures. In 1950 the Highland Fertilizer Scheme demonstrated promising herbage-yield responses to phosphorus and to nitrogen by certain natural and established pastures. Marked beneficial effects of phosphorus on ley-establishment were demonstrated also. In 1951 the Department of Agriculture sought to obtain a preliminary assessment of optimum dressings of a phosphatic fertilizer (single superphosphate) and a nitrogenous fertilizer (sulphate of ammonia) for natural and established pastures, and for establishing leys, on different kinds of soil and in areas of varying altitude and climate.

In this paper an attempt is made to summarize the main results obtained from these latter investigations.

The field trials on natural and established pastures were composed of replicated factorial combinations of three levels of single superphosphate (P) and six levels of sulphate of ammonia (N). The fertilizers were broadcast at the beginning of the 1951 growing season and nitrogen was applied at the appropriate level after each herbage cut had been taken. Ley-establishment trials were composed of replicated factorial combinations of four levels of P and four levels of N, the fertilizers being placed in the seed bed only. One of the following grasses—Rhodes, molasses, cocksfoot, K31 fescue—was sown with lucerne or with serradella. The herbage in all trials was cut at intervals when the sward reached a stage of growth considered suitable for stock-grazing. Soil samples to a depth of six inches were taken from each plot of each experiment for pH determinations.

The nitrogenous fertilizer applied to natural and established pastures and to the seed bed of newly sown leys was found to increase the yield per acre of dry matter, crude protein, lime (CaO) and phosphorus (P_2O_5). In respect of natural and established pastures, dry matter response to N conformed to a calculated logarithmic curve. The system adopted of re-applying N to these pastures after each herbage cut was found to enhance their productivity during the growing season. No interval application of N was made to newly sown leys but a single dressing to the seed bed in adequate amount (approximately 1½ cwt. sulphate of ammonia) usually assisted establishment. Measurable residual effects were rarely obtained from subsequent cuts except occasionally at the higher levels of application.

Applications of the phosphatic fertilizer to natural and established pastures and to the seed bed of newly sown leys were found to increase the yield per acre of dry matter, crude protein, lime (CaO) and phosphorus (P_2O_5). Calculated response curves to P in respect of dry-matter yield from natural and established pastures and from newly sown leys resembled closely those given by Crowther and Yates [2] for root and cereal crops in England. The main

* A detailed account of this work is to be published in the Empire Journal of Experimental Agriculture.

effect of P on newly sown leys was undoubtedly to promote their establishment. An adequate dressing depended on soil and locality but rarely was required to exceed 3 cwt. of single superphosphate. A residual effect after the first cut was reflected in the phosphorus content of the herbage but seldom in dry-matter production. With natural and established pastures, however, some evidence of residual effect was obtained through its enhancement of yield increases obtained by re-applying N at approximately 1–1½ cwt. sulphate of ammonia per acre.

A known effect of adding sulphate of ammonia to a soil is to cause, eventually, an increase in soil acidity [3]. This effect was demonstrated clearly in the soils of newly sown leys and of natural and established pastures, when the fall in pH was related directly to each increment of N applied.

E. M. Crowther [4] has related pH to response to P for crops such as swedes and turnips. A similar relationship between pH and response to P was found for natural and established pastures in Kenya: a less convincing relationship was found for newly sown leys. Evidence was obtained in 1952 which suggested that the amount of phosphorus taken up by the herbage of natural and established pastures may also be related to pH.

Rainfall in Kenya is neither well distributed nor reliable yet the need for adequate moisture in relation to normal plant growth in the presence or absence of fertilizers is obvious. In 1951 it was found with newly sown leys that at every increment of N applied to the seed bed, yields of herbage could be related directly to the rain which had fallen during the month prior to cutting. No corresponding relationships were found with natural and established pastures, and this may be ascribed, in part at least, to the presence of more favourable soil-moisture regimes. The efficiency of the phosphatic fertilizer in herbage production was found also to be dependent on rainfall. For newly sown leys, and for natural and established pastures, responses over control yield were related directly to the rain which had fallen during the month prior to cutting.

At high altitudes, plant growth tends to be slow and the Kenya Highlands are no exception. In 1951 it was possible to relate altitude directly to the number of days required to obtain an initial cut from newly sown leys.

Available information suggests that under a given environment, a dominant species in a ley sward or in a natural sward will behave similarly in its response to N and to P.

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Fertility Responses—Ukiriguru

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This paper deals with fertility responses at the experimental station, Ukiriguru, in the Lake Province of Tanganyika, obtained since the last symposium on fertilizer responses in 1949 (*vide* this Journal, Vol. 15, 1949, p. 61). The soils on which the field trials were carried out are hill sands of the granite catena, which were described as the Granitic Red Soils by Morison and Wright. The main indicator crop was cotton, rotated with bulrush millet. The trials were laid down on broad-based tied ridges, 5 ft. wide. With tie-ridging there is no rain run-off, and on the whole, rainfall and soil moisture for the growing crops have been as good during the past three years as can be expected in this area.

Summing up the present views for these hill sands, the main conclusions that can be drawn are as follows. Organic dressings (up to seven tons per acre farmyard manure or compost) give very worth-while responses, especially on land in fairly low fertility—these responses persist for a considerable number of years; with higher fertility, responses are generally lower, and in one trial under such conditions they were not significant. In trials where organic responses have been obtained, phosphate responses (using superphosphates) do not always show. When reasonable responses do show there may be little increase from a double application of superphosphate. There can be residual responses from phosphate applications. With regard to nitrogen, in an early experiment where sulphate of ammonia was applied at planting there was no nitrogen response, but in later experiments there have been good nitrogen responses with sulphate of ammonia as a top dressing. The effects, so far

as they have been measured, were for the year of application only. Potash applications have given no yield responses. On worn-out land there have been considerable yield increases following tumble-down fallows, consisting predominantly of the small composite weed *Tridax repens*, which quickly establishes itself on worn-out land. It has been suggested that the effect of *Tridax repens* is to make phosphate available to the succeeding crop.

The most striking results in these experiments has been the residual effect of organic dressings, either farmyard manure or compost, the effects of which (at seven tons per acre or three tons per acre) have persisted for eight years on cotton rotated with bulrush millet. Equivalent amounts of nitrogen and phosphate gave results similar to, or greater than, these organic dressings, but only in the year of application, and as yet there is no full explanation of the long-continued organic residual response after allowing for the residual phosphate contribution. Nitrogen, top-dressed, following on an organic dressing, direct or residual, raises the yields in the year of application: this would probably be economic for a European farmer, but in peasant farming economy the risk of crop failure may be too great to permit him to spend money from which, in some years, he may not get a full return.

The early responses to applications of Kenya sodaphosphate were poor, but the trials were carried out at the start of the fertilizer work at Ukiriguru. Since then the results of phosphate applications, using single and triple superphosphate, have been varied—from good, very well worth-while responses, to none. Phosphate dressings for application by Africans, supported possibly by top-dressings of sulphate of ammonia, are now being tested, but it seems likely that some time would elapse before the Africans of the Lake Province of Tanganyika would be willing to use inorganic fertilizers.

A three-year tumble-down fallow has given very promising increases in the subsequent crops, even although the fallow had a sparse and unimpressive appearance. In peasant farming, soil improvement by rest under natural fallow would be a great asset: the effect of a five-year fallow is excellent, but even a short fallow of less than three years would appear to be well worth while.

The Responses of Wheat, Tobacco and Pyrethrum to Fertilizers in the Southern Highlands of Tanganyika

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In May, 1949, an Agricultural Officer was posted to the Southern Highlands Province of Tanganyika to extend the experimental work there: prior to 1949, few experiments had been carried out on fertilizers in this province and these had been on large plots without statistical design. Field trials during the past three years have been mainly concerned with wheat, tobacco and pyrethrum and have included fertilizer responses, varieties, cultural methods, planting distances, seeding rates, and times of planting.

In the Southern Highlands the high cost of fertilizers is of paramount importance: at present, double superphosphate costs £55 per ton at Iringa, the nearest town to the railhead, and other fertilizers are similar in price.

In the Iringa District, on a granitic soil, fertilizer trials on wheat over the three years have given significant responses to double superphosphate at 50 lb. P_2O_5 per acre, but no additional significant response was obtained at 75 lb. P_2O_5 per acre. Farmyard manure at five tons per acre and muriate of potash at 50 lb. K_2O per acre also gave significant responses. Responses were also obtained with sulphate of ammonia at 15 lb. and 21 lb. N per acre, but these were not statistically significant. In general, farmyard manure proved to be the most valuable single fertilizer, and when it was supplemented by phosphate or nitrogen further increases in yield were obtained. In all cases where potash was combined with phosphate there were marked increases in yield. The highest yield of all was given by 21 lb. N, 50 lb. P_2O_5, and 50 lb. K_2O, but the cost of this treatment is high, from £5 to £8 per acre. In a good year this would give a reasonable profit but the capital outlay is greater than many farmers would be prepared to consider, in view of possible crop failures due to drought, rust, or other causes. Under average seasonal conditions, the most profitable dressings seem to be five tons F.Y.M. with 15 lb. N or 50 lb. P_2O_5, but where F.Y.M. is not available 50 lb. P_2O_5, plus 50 lb. K_2O seems to be the best substitute. Sodaphosphate appeared to be as effective as an equivalent dressing of superphosphate, but the high cost of transport makes it essential to supply the phosphate in as concentrated a

form as possible. Placement trials showed that correct placing of phosphate is essential, and broadcast phosphate had little effect.

In the Mbeya District, to the south of the Province, the soils of the Poroto Mountains are of volcanic origin and are generally regarded as being very fertile, but an experiment in 1952 gave remarkable responses to F.Y.M., while N.P.K. and lime did not give profitable returns. Since Mbeya is some 200 miles farther from the railhead than Iringa, very definite profitable responses to inorganic fertilizers would be required before it would be wise to apply these, and at present the only recommendation is that F.Y.M. should be applied at about five tons per acre.

With tobacco, gross yields mean very little by themselves, since it is the quality of the leaf which counts most. Therefore quality as well as quantity was measured in the field trials at Iringa, and the extra work in grading after curing gave many opportunities for errors to arise: owing to high standard errors in the analysis of the results, responses of obvious practical importance sometimes failed to reach statistical significance. For example, no statistically significant increases in gross yield resulted from the application of fertilizers, although there was a difference of 900 lb. per acre between the highest and the lowest plot yields. Nitrogen at 9 and 18 lb. N per acre as sulphate of ammonia depressed the yield when applied by itself, and when combined with 30 or 60 lb. P_2O_5 as double supers, or 24 or 48 lb. K_2O as muriate of potash gave yields little better than the control. (Sulphate of potash was not obtainable at the time of the experiments.) Yields increased appreciably when N.P.K. were applied together, and K by itself gave increases which were directly dependent on the amount applied, up to 48 lb. K_2O per acre. The highest yields were given by 30 lb. P_2O_5, 48 lb. K_2O, and either 24 or 48 lb. N, in combination, and these dressings also gave the highest percentage of high-grade leaf (about 78 per cent) and the highest revenue per acre, the latter being an increase of over £50 per acre above the average gross revenue.

Of the three crops studied, pyrethrum has given the most remarkable responses to fertilizers, in particular to superphosphate. The work was done in the Njombe District some 200 miles SSW. of Iringa, where the soils are formed from granite and appear to be deficient in phosphate judging by analytical data. Muriate of potash (up to 150 lb. per acre) had no significant effects on yield: if anything, lime depressed yields. In one experiment, sulphate of ammonia (up to 200 lb. per acre) gave a linear response each year which just failed to be statistically significant. On one farm, compost had no effect on yield, but on another, five tons compost per acre gave a significant response of 127 lb. pyrethrum per acre over the total of two years' yields. Increasing the application to ten tons per acre had no additional effect. Superphosphate, placed in the base of the ridge before planting, had a remarkable effect, causing a large and significant increase in all four experiments in which it was applied. On one farm no response was obtained from 150 lb. double supers per acre, but 300 lb. gave a large significant response. On two farms the response was linear and significant and on the fourth farm there was a significant response at 150 lb. but no further increase at 300 lb. These responses occurred in each experiment in each of the three years of trial and were significant for each year and for the total yields of the three years.

In general, 300 lb. double superphosphate per acre appears to be an economic dressing, but 200 lb. seems to be as much as is likely to be used in practice, since at that rate of application the fertilizer costs about £5, plus cost of applying it.

Responses to Fertilizers in Areas of Tanganyika Farmed by the Overseas Food Corporation

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During the five years 1947–52, some 280 fertilizer experiments have been carried out on the corporation's land in Tanganyika (Kongwa, Nachingwea and Urambo), about half of these being on groundnuts and maize: of the remainder, only those on sorghum are discussed. Trials with sunflower are not included as the crop has proved to be unsuitable in all areas and yields were poor: a few experiments with castor, soya bean, safflower, niger oil and tobacco have also been carried out, but the results of these are not included as the crops are of minor importance, and with each crop there were only one or two trials. A number of the experiments were lost through drought, disease, and damage by animals.

Groundnuts have responded to phosphate in all areas, but not to nitrogen, potash, or calcium. At Kongwa the response has been confined to the upland soils and has varied from year to year; in 1948 and 1952 an increase of 160 lb. kernels per acre was obtained from 0.5 cwt. P_2O_5 per acre, either as single or as triple superphosphate, the average response over the five years being 100 lb. At Nachingwea, over four years, the response to 0.5 cwt. P_2O_5 per acre has been higher than at Kongwa, averaging 150 lb. kernels per acre, although the mean annual response has varied from 80 to 190 lb. At Urambo the experiments have been seriously affected by rosette disease in two years, and by the relatively poor rainfall of 1949. Thus only the experiments of 1950 are available to give an estimate of the response to phosphate, and in that year the yellow-brown loamy sands and the grey sands gave responses of 170 and 120 lb. kernels per acre respectively: the response on the red loams was negligible.

There is evidence from Kongwa and Nachingwea that 0.2 cwt. P_2O_5 per acre would give responses almost as good as those given by 0.5 cwt. The variation in the response to phosphate from year to year, particularly at Kongwa, is probably associated with the nature of the rainfall, the season's total often being irregularly distributed. In 1949 the virtual cessation of the rains at the end of February caused widespread crop failures in Tanganyika, and the necessity for conserving all the rainfall in the soil has always been recognized: methods for maintaining a reserve of soil moisture from one season to the next are under investigation.

Maize, like groundnuts, has not responded to potash or calcium in any area, but nitrogen and phosphate together have increased yields in all areas, the normal dressings per acre being 0.4 cwt. N as sulphate of ammonia and 0.5 cwt. P_2O_5 as triple or single superphosphate. Data for Kongwa are scanty, but in three experiments there were responses to phosphate in the presence of nitrogen varying from 240 to 600 lb. grain per acre. At Nachingwea both nitrogen and phosphate given alone increased the yields, and there was a high NP interaction: in 14 trials the average control yield was 1,160 lb. grain per acre, the response to N being 320 lb., that to P being 190 lb., while N and P together gave an increase of 700 lb. Nine experiments at Urambo gave, on the average, a control yield of 920 lb. grain per acre, with a response to nitrogen of 420 lb. Phosphate alone gave no increase in yield, but nitrogen and phosphate together raised the yield by 660 lb. The nitrogen response, given by 0.4 cwt. N per acre, was not much greater than that given by 0.2 cwt. At Urambo the date of planting maize affected the size of response to nitrogen as well as its yield without nitrogen: the response in two trials fell off consistently with the later plantings.

Although sorghum is of considerable importance at Kongwa, little information concerning its response to fertilizers is available, but increases of about 200 lb. grain per acre have been obtained from 0.5 cwt. P_2O_5 per acre. In 1952, birds caused great damage to the crop and all experiments were lost.

The residual effects of phosphate have been studied at Kongwa and Nachingwea, but no positive results were obtained at Kongwa. At Nachingwea, residual phosphate has increased the yield of groundnuts following Sudan grass, maize and groundnuts, about 100 lb. extra kernels being given. Although more work is needed on this point, it seems likely that the most efficient use of 0.5 cwt. P_2O_5 per acre would be to apply it to maize, groundnuts in the following year using the residual phosphate. It is possible, however, that a smaller application to maize or to both crops would be as effective, or more so.

At Urambo, farmyard manure at ten tons per acre gave a mean increase in the first-year maize crop of 380 lb. grain per acre. Nitrogen and phosphate together gave an increase of about 450 lb., both in the presence and in the absence of farmyard manure. In the second year the residual effect of farmyard manure increased the groundnut crop by 200 lb. kernels per acre.

Recent Fertilizer Trials in Uganda

W. R. Mills, Uganda Department of Agriculture

This paper describes the fertilizer experiments that have been carried out by the Uganda Department of Agriculture following on the earlier work of Manning and Griffith [1]. The results of the previous work may be summarized as follows. Nitrogen at the rate of 1 cwt. per acre sulphate of ammonia gave responses in a wet season of up to 25 per cent for finger millet and 16 per cent for maize: double this application

gave responses of 40 per cent and 24 per cent respectively. During a dry season no benefits were obtained with maize. Responses to phosphate were extremely disappointing except on a single very acid soil where double superphosphate produced a 30 per cent increase in sorghum yield. No responses have been obtained with potash on account of the general high level of this nutrient throughout the Protectorate. Applications of fertilizers to cotton produced variable results: nitrogen produced as much as 19 per cent increase at Serere while at Kawanda it produced in some years a negative response or at best only an 8 per cent increase on a free bolling variety. Yield responses to phosphatic fertilizers were on the whole very small, the highest being one of 13 per cent to sodaphosphate at Serere.

It is possible, however, that the poor responses to phosphate in the majority of the early trials were due to the fact that rock phosphate was used in only small dressings whilst the sodaphosphate then available inhibited germination. Conclusive evidence that many of the soils in Uganda do not respond to phosphate cannot thus be stated.

Manning and Griffith indicated the reasons for variable response to nitrogen in the seasonal build-up of nitrate in the soil, and subsequent experiments with sulphate of ammonia have been laid out with the idea of giving it to the plants when they are most in need of it. The trials of Manning and Griffith are being repeated on a long-term basis with modifications in design and with the ultimate object of increasing the cotton crop which eventually fitted into the rotations. The major issue was whether or not it is better to fertilize cotton directly or to rely on the residual effects of application to previous crops.

Three new phosphate experiments were begun in 1951, at Kawanda, Namulonge (run by the Empire Cotton Growing Corporation), and Kagongo, to compare the direct effects on maize and the residual effects on cotton of 63 and 126 lb. P_2O_5 per acre as Uganda rock phosphate, sodaphosphate, and single superphosphate in the presence and absence of sulphate of ammonia at 2 cwt. and 4 cwt. per acre. The phosphates were broadcast and worked into the seed bed and the sulphate of ammonia was applied a month after planting.

At Kawanda, on a relatively infertile earthy red latosol, in an abnormally wet year, maize, and the subsequent cotton crop (both crops being of high yield) benefited by the application of fertilizers, the maize crop giving increases of 66 per cent and 97 per cent with sulphate of ammonia at 2 cwt. and 4 cwt. per acre respectively. Phosphates also increased the yield, and rock and sodaphosphate tended to be more beneficial than superphosphate: a crop increase of about 19 per cent was obtained with sodaphosphate at 3 cwt. and rock at 15 cwt. per acre. The cotton crop seemed to suffer slightly from the heavy demand on nitrogen by the preceding maize crop, but a second dressing of sulphate of ammonia at 2 cwt. per acre applied to cotton at flowering gave a 19 per cent increase in yield. Sodaphosphate at 6 cwt. per acre had more of a beneficial residual effect than did the other phosphatic fertilizers, but the 10 per cent yield increase which it caused was not economic.

The Namulonge trial, on a soil similar to that at Kawanda, also had an abnormally wet year, the control yield of maize being 3,400 lb. grain per acre. Neither rock, soda, nor single superphosphate increased the yield significantly, but 2 cwt. sulphate of ammonia gave a 51 per cent increase while 4 cwt. gave 75 per cent increase which was not so profitable as that from the lower dressing. The cotton crop which followed the maize showed a residual phosphate effect of 18 per cent which was approximately the same for all types of fertilizer. There was no residual nitrogen effect, but a second dressing of 2 cwt. per acre sulphate of ammonia increased the yield by 16 per cent, which was not sufficient to pay for the fertilizer.

The trial at Kagongo also had a wet year, and the soil, a yellow latosol, which had been rested for three years under grass which was grazed, gave a heavy crop of maize which was not increased by applications of any of the phosphatic fertilizers either with or without sulphate of ammonia. The succeeding cotton crop failed, possibly owing to excessive manganese in the soil.

Single heavy dressings of phosphate, up to 30 cwt. single super, rock, and sodaphosphate, are being tested on a yellow latosol at Buwunga in the Masaka District on finger millet followed by sorghum and then by cotton. Nitrogen was also applied separately as nitrate of soda, but this depressed the first yield slightly and had no residual effect. The phosphate dressings were not economic, although responses were obtained; the residual effects of

soda and superphosphate increased the cotton crop by 47 per cent and 57 per cent respectively. A mulch of *Imperata cylindrica* was also applied as a treatment in this experiment, and it was kept at about 6 in. thick. Its effect was outstanding, in that the yield increases in the sorghum and cotton crops were nearly twofold and sixfold respectively. On account of the wet season, millet yields were depressed by the mulch.

REFERENCE

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Crop Responses to Fertilizers and Manures in Zanzibar

G. E. Tidbury, Zanzibar Department of Agriculture

Although a limited amount of investigation into the manurial status and needs of Zanzibar soils was done in the years before the last war, by far the greater part of the present knowledge has been gained during the past six years. Previous field trials were carried out mainly on coco-nuts, cloves and pineapples, but the work on coco-nuts, one trial on which lasted ten years, gave conflicting results which are now known to be caused by movements within the experimental area of the Theraptus pest and its predators. Results from clove experiments were also hard to obtain. Young plants in the nursery failed to respond to any manures until the third or fourth year, and mature trees could only be made to show a positive response to heavy dressings of coconut meal. Between these age extremes, young saplings in the early bearing years produced small but profitable yield increases from dressings of sulphate of ammonia, and yet smaller increases due to potash. Experimentation with cloves is now in abeyance pending elucidation of the sudden-death disease problem.

A series of field experiments with pineapples was carried out from 1940 onwards, and, as far as the results apply to the one soil type on which the trials were conducted, the effect of fertilizers were fairly fully explored. Nitrogen, as sulphate of ammonia, increased the yield in the first two harvests by increasing both the number of fruit reaped and the average size of the fruit. In the third harvest (i.e., the second ratoon), probably as a result of heavy bearing in the first two seasons, the nitrogen-treated plots bore fewer fruit, although increased size was maintained. In the fourth and fifth seasons, the largest suckers having been replanted, nitrogen again increased the size and number of pineapples. Potash had no positive effects until the fourth and fifth seasons, and phosphate without nitrogen never caused positive responses and even tended to decrease yield.

In 1947, W. E. Calton classified the soils of Zanzibar Island and found three main types; the *kinongo* soils which are loams of varying depth derived directly from limestones, usually coral; the *changa* soils which are on non-calcareous sediments and which range from deep, reddish-brown, fertile soils to grey and yellow sluggishly draining and relatively infertile soils; the *namo* soils which are sticky and heavy, often suitable for rice-growing. The soils of Pemba Island were also typified, but fewer field experiments have been carried out there.

On the *kinongo* soils, nitrogen as sulphate of ammonia gave striking increases in yield; maize yield increases ranged from 80 per cent with 1 cwt. per acre to 240 per cent with 3 cwt., and sorghum increases ranged from 50 per cent with 1 cwt. to 200 per cent with 3 cwt. Phosphates have never caused crop increases on these soils, but potash has occasionally given excellent responses, and there is little doubt that potash assists cereals to grow away from borer attack. Compost has also given responses, yams in particular giving very greatly increased yields by its application.

Changa soils also need compost and on them crops also respond markedly to nitrogen, but there appears to be a fairly low limit to the quantity of nitrogen that will produce economic results. Dressings as high as 3 cwt. per acre of sulphate of ammonia will often produce very large increases, but when costs are considered, 1 cwt. per acre is roughly best for cereals, including rice, on *changa* soils. Much of the value of nitrogenous dressings is indirect, in that, when applied together with phosphate, marked positive interactions are usually observed. But the main need of *changa* soils is for phosphate, and field trials using single superphosphate have given as much as 100 per cent increase in yield of maize at 2 cwt. per acre, 284 per cent increase in sunflowers at 2 cwt. per acre, and 200 per cent increase in rice at 3 cwt. per acre. Crop responses to potash on these soils are very rare.

All the experimental work on the *namo* soils has been with rice, and these soils generally respond to nitrogen and phosphate, but not to potash. The demand for phosphate

is definitely less than that of the *changa* soils, and the maximum economic dressing is apparently in the neighbourhood of only 1 cwt. per acre. Compared with *changa* soils the nitrogen requirement of some *namo* soils is relatively great. In one area (Cheju) rice will pay handsomely for dressings up to 3 cwt. per acre but in another area (Muyuni) the value of nitrogen has lain largely in interactions with phosphate. It is perhaps possible that this difference is connected with the predominant Muyuni practice of rotating rice with pulses, which is not done at Cheju.

Less is known about the soils of Pemba Island, and field experiments have been fewer than in Zanzibar Island and have been confined to those soils which are generally used for food production. On the whole, nitrogen and phosphate frequently give responses, humus is needed, and potash is irregular in its effect. One soil (*mtifutifu*) which closely resembles the Zanzibar *changa* has given striking yield responses to sulphate of ammonia on rice, a fivefold increase being obtained with 2 cwt. per acre in one experiment, with smaller but still striking responses in others.

Liming has also shown definite beneficial effects on the more acid soils of Zanzibar, and by bringing the pH of the soil to 6.5, responses to lime have been obtained with sweet potatoes and rice, but the reaction is not clear, since reduced yields after liming have been just as frequent as positive responses, and in micro-plot surveys of Zanzibar and Pemba, lime frequently reduced yield, possibly by inducing minor element deficiencies.

Increased local fertility as a result of burning bush or grass when preparing the land for planting is commonly observed, especially in rice fields, where a patch of bright green vigorous vegetation marks the site of a fire. On a large scale, the system of shifting cultivation practised on the coral *karst* land includes a carefully regulated fire of cut bush which local cultivators consider essential. At a coral area experiment station in Zanzibar, attempts were made to provide fertile conditions without burning the bush. This experiment was continued for over four years, and dressing of fertilizers and compost were applied to the unburnt area. But the effects of the original burn were still evident after four years' cropping, and neither artificials nor compost could supply equivalent fertility, either at the time of application or as residual effects.

Effects of Fertilizers and Manures on Kenya Coffee

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The wide variation in coffee plantation practice and opinion is explained by the complexity of factors which mask the results of simple "trial and error" observations on coffee trees. The Kenya coffee industry has in the past spent very large sums both on phosphatic fertilizers and on manure from native cattle *bomas,* while until very recently nitrogen dressings have received very little attention.

Results for five years of an 108-plot factorial field trial at the Coffee Research Station, Ruiru, are summarized. No response in yield or quality, and no beneficial subsidiary effects such as earliness of ripening or restriction in die-back have been obtained from five annual dressings of sodaphosphate at 2 cwt. per acre (45 lb. P_2O_5 per acre), Uganda rock phosphate at 3¼ cwt. per acre (90 lb. P_2O_5 per acre) or cattle manure at either 3½ or 7 tons per acre. Where the treatments occurred together the phosphates were incorporated in the manure in order to reduce the possibilities of fixation by the red lateritic clay soil. Evidence that the coffee did in fact obtain extra phosphates from the treatments was obtained from results of foliage analysis. Sulphate of ammonia had no effect at 1 cwt. per acre but significantly increased yields in two years out of five when applied at 2 cwt. per acre. Over five years this gave a significant yield increase of 7 per cent, a result which showed a moderate economic profit. This trial was capable of detecting a 6 per cent yield difference at the 5 per cent level of significance for five-year total yields so that the evidence of lack of response was well established. This confirmed a considerable amount of evidence from smaller and earlier Kenya trials, in a variety of soils and climates, the results of which had not previously been reviewed and presented.

Additional evidence of lack of response by mature coffee trees to *boma* manure is supplied by an 81-plot factorial cultivation trial in which plots were split for the standard annual dressing of one 4-gallon tin per tree (3 to 4 tons per acre) which remains the practice in many large estates. Over five years this trial has been capable of establishing a 3 per cent difference in yield, but no significant response has been obtained.

A smaller manurial trial is described in which larger annual dressings are tested. Four cwt. per acre of sulphate of ammonia, 2 cwt. per acre of double superphosphates and 4 tins per tree (14 tons per acre) of cattle manure are combined factorially. The heavy nitrogen applications have given a yield response of 27 per cent over the first three years, which has been both statistically and economically significant.

The very great effect of rainfall on yields in the main coffee-producing areas of Kenya east of the Rift is illustrated graphically; a 100 per cent increase in annual total rainfall (which fluctuated during the trials between 24 and 56 in.) more than doubled the crop. This sensitivity of yields to water supply explains the highly successful effects of grass mulching. Organic matter applied as a grass mulch has been shown by field trials to increase yields whereas organic manure dug in as cattle dung has failed to do so. Recent soil moisture studies have shown that mulch should be applied before instead of after the wet seasons, since its quantitative effect on soil moisture was far greater in assisting the penetration of rainfall than in impeding its subsequent evaporation. When applied before the rains an all-row mulch has raised a low yield in a dry year by 100 per cent, and a good yield in a wet year by 75 per cent.

The phosphate contents of grass mulches applied during these trials are shown to be greatly in excess of the loss of phosphates in the coffee crop. The quantities of nutrients removed from the soils on which mulching grasses are grown are correspondingly high, and it is at this point in the coffee plantation system that fertilizers should be added. The techniques of fertilizer supply to mulch grass areas are still unknown, and field trials, recently begun, have not yet given consistent results. The practice of applying the available cattle manure to the grass instead of to the coffee has been adopted at the Rukera Demonstration Farm at Ruiru.

The work summarized has been performed in the author's capacity as a member of the Kenya Coffee Research Team, and the field trials have been conducted jointly with the Agricultural Officer of the team, Mr. P. A. Jones.

A Review of the Fertilizer and Mulch Experiments on Coffea Arabica in Tanganyika

F. R. Sanders, Tanganyika Department of Agriculture

The cycle of nitrate accumulation, leaching, and replenishment in the soils of the Coffee Research Station, Lyamungu, has been studied by Stent. He found that, given climatic conditions suitable for the release of nitrate, a generally high level of nitrate could be expected, but the intensity of rainfall during the months of April and May can be such that the nitrate which has accumulated in the surface layers is soon leached below root level, and the rate of replenishment is slow owing to conditions unfavourable to nitrification. It may be some time before adequate supplies of nitrate are again released and distributed in the root zones. This low level of nitrate occurs when the coffee cherry is developing, and in years in which heavy long rains occur the leaves may show chlorosis.

When the behaviour in the soil of various kinds of nitrogenous fertilizers was investigated, it was found that nitrates as such were rapidly leached into the lower soil horizons when applied during the rains: when nitrogen was applied as ammonia, it was first retained in the surface soil and converted into nitrate over a period of three to five weeks, the nitrate being leached downwards according to the amount of rain falling.

In 1936, experiments were laid down on ten estates in the Northern Province to determine the effect on yield of sulphate of ammonia applied to mature coffee when the nitrate in the soil is at a low level. At the rate of 8 oz. per tree it effected a useful increase in all cases except one, but in only one trial were the tests for statistical significance satisfied. In 1940 a trial was planted at the Coffee Research Station in which the treatments were mulch (elephant grass), compost, and sulphate of ammonia, each at three levels. The plots receiving sulphate of ammonia alone have shown an increase in yield over the control plots during the ten-year period of the experiment, but this increase was not statistically significant. The compost plots did show a significant 22 per cent increase in yield (1.76 cwt. per acre), at the rate of 40 lb. compost per tree, without added advantage when the dressing was doubled. In the same experiment, applications of dry elephant grass at 40 lb. and 80 lb. per tree did not give a significant

increase, although the yields did show an improvement on the nil plots.

In another trial on the Coffee Station, in which the treatments were guinea grass, elephant grass, and banana trash as mulches at 80 lb. per tree, and compost at the same rate, with split plots receiving sulphate of ammonia, the results over a ten-year period show that sulphate of ammonia has not caused any increase in yield. But the application of dry banana trash as a mulch in June each year, at the rate of 40 lb. per tree has resulted in an increase in the mean yield, over a ten-year period, of 2.67 cwt. per acre (50 per cent) with unshaded, single-stem coffee. Higher rates of application were no more effective.

Twelve years after the establishment of the Coffee Research Station, a study was commenced of the organic matter content of the soil in relation to the various treatments such as organic manuring, inorganic nitrogen, and mulching. Banana leaf trash had increased the organic matter content considerably, but other mulches had not, nor had nitrogenous fertilizers. It would seem, therefore, that the effectiveness of banana trash may be due, in part at least, to its manurial value, particularly as the June application of 40 lb. per tree ceases to give an effective cover by December. Furthermore, applications of 80 lb. per tree, although they give an effective cover for a longer period, do not cause a further increase in yield. In order to supply trash at 40 lb. per tree it requires double the acreage of bananas to coffee, and the feasibility of applying banana trash at all will vary with each estate and will depend on the returns which could be obtained from the land when it is used for something other than bananas. Excluding the cost of planting the bananas, and the value of the land on which they are grown, the cost of mulching is approximately Sh. 90 per acre; this includes weeding the bananas and cutting and applying the mulch. The production and application of compost at 9–10 tons per acre is also a question for the individual estate, and it may not always be a practical proposition.

At Mbosi, in the Southern Highlands Province, there is a certain amount of evidence that sulphate of ammonia is beneficial on soils derived from syenite, but phosphates have had no effect even although analysis of these soils shows a low phosphate status. However, there is some evidence that throughout the Mbosi area the coffee is affected by a manganese-induced calcium deficiency, and, should it be proved that this condition exists and can be corrected, the effects of fertilizers may be very different.

[*Since this paper was written it has been found that by clean-felling an area of bananas, sufficient mulch, using stem (split) and leaf, is obtainable from one acre to mulch one acre of coffee. As a result of clean-felling, suckers come away in quantity and grow quite quickly. There are indications that a further clean-felling will be possible within a year, in which case one acre of bananas may be sufficient to mulch 1½–2 acres.*

The question of how often an area can be clean-felled and still maintain production of mulch at this level will be investigated.]

The Manuring of Tea

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As the Tea Research Institute of East Africa was only recently established, and its manurial experiments are only in the preliminary stage, this paper deals mainly with the general effects of fertilizers on tea in other parts of the world, particularly Ceylon. The fact that the cropped fraction of the tea plant is leaf in its most active stage of growth leads to the removal of appreciable quantities of mineral nutrients. The nitrogen content of the "flush" is 4 to 5 per cent of the dry matter, the potash content may be as high as 2.5 per cent, and phosphoric acid is lower with an average figure of less than 1 per cent. Balance sheets of nutrient use and removal show that in the crop and pruning wood that are habitually removed from tea fields, a thousand pound crop accounts for about 65 lb. nitrogen, 35 lb. potash, and 15 lb. phosphoric acid.

The most widely used fertilizers in tea cultivation are the nitrogenous group, and of these sulphate of ammonia is generally preferred. Being physiologically an acid fertilizer it introduces no complicating pH factor, for tea will thrive only on soils below a pH value of about 6.2. Other forms of nitrogen have been used, but they are never competitive from the standpoint of unit price. The responses to varying doses of nitrogen depend directly on the amount applied, up to 80 lb. N per acre: this was determined from a continuous series of annual applications extending over 18 years. The regularity of response in spite of variation of climate suggests that

absorption of nitrogen by the plant is rapid and is affected by environmental conditions during a short period only, and it is a matter for conjecture whether a significant factor in tea manuring is a direct absorption of ammonia free from the complications of nitrate loss.

Despite the lower figures for phosphate absorption the yield responses to this nutrient are significant and immediate, but, unlike nitrogen responses, they are not proportional to the rate of application. At the two rates used, 30 lb. and 60 lb. P_2O_5 per acre per annum, both treatments showed statistically equivalent responses, and the extra 30 lb. was wasteful under the conditions of the experiments. Analysis of the tissues of crop showed that above 30 lb. per acre there was luxury consumption of phosphate.

Many tea soils are, by ordinary standards, well supplied with potash, but the drain on potash resources is large. This is not only due to the demands of the tea plant itself, but also to the intake by weeds which are traditionally removed at regular intervals. Under Ceylon conditions the soft weeds associated with tea plantations contain some 3.5 per cent of potash in the dry matter and a three-month cover of weeds can account for more than 20 lb. of K_2O. For 11 years after the start of the Ceylon experiments there was no sign that applications of potash at the rates of 20 lb. and 40 lb. per acre per annum had any effect on yield. Since then there has been evidence of a progressively increasing deficiency that has affected every part of the plant and has led to defoliation and eventual death of bushes. In contrast to this delayed effect of potash deficiency on mature tea, there is an apparent immediate effect on young tea on virgin soil, and it is possible that sheer lack of a large enough root system may hamper young plants in obtaining their due requirements.

Interest in the use of bulk manures in tea cultivation was stimulated some years ago by the advocacy of composting by the late Sir Albert Howard and by the severe fertilizer rationing that was imposed during the war. One example of the effects of combined applications of compost and fertilizers will be of interest. On an experimental area of young tea not yet in bearing, Adco compost was applied in four successive years at the rate of 15 tons per acre, providing in all 540 lb. of nitrogen. Subsequently single (40-lb.) and double doses of nitrogen were superimposed on composted and control areas. The beneficial effects of the bulk manure were still operative 12 years later, and the efficiency of the superimposed nitrogen was much greater when applied to the compost than when applied alone.

Sisal Manurial Trials*

G. W. Lock, O.B.E., Tanganyika Department of Agriculture

At the present time manuring hardly enters into the practice of sisal cultivation, but growers are beginning to give more attention to this subject. Sisal-growing is an extensive form of monoculture which has hitherto relied upon the fertility reserves of large areas of new land for maintaining the productivity of estates: some soils have carried sisal continuously for nearly 50 years, but, latterly, soil exhaustion has become evident in declining yields and the appearance of deficiency diseases.

Although the Sisal Research Station in Tanganyika has been conducting fertilizer trials for some years, little progress has been made in this connexion until recently. The early experiments which were sited on virgin soil (a deep acidic red earth derived from gneiss), did not show marked responses to fertilizers, and the small visual differences attributable to nitrogen and phosphate proved to be transitory and did not affect final yields (15 tons of fibre per hectare). The sisal grew so well that it was difficult to bring about any improvement, and it was concluded that fertilizing sisal on suitable new land would be uneconomic.

When the second cycle of sisal on the same land failed to give responses to fertilizers, in spite of the fact that fibre yields had fallen by 3 tons per hectare, it was inferred that the rates of application were too low, and also that better placement might have prevented losses through fixation and leaching. Much heavier rates of application were therefore adopted for the third cycle of sisal, and this experiment, which has been running for 3½ years, is now providing interesting results.

* Acknowledgment is due to the Tanganyika Sisal Growers' Association for permission to publish this summary.

Yield data for the first cutting cycle of this 3^4 factorial experiment, incorporating lime, nitrogen, phosphate, and potash, each at three levels, have shown small but significant responses to Ca, N and P but none to K: these responses are expected to be larger in later cuttings. The rates of application at the lowest levels were as follows: lime as ground limestone at 6,000 kilos per hectare*, nitrogen as sulphate of ammonia at 100 kilos N per hectare, phosphate as double superphosphate or sodaphosphate at 100 kilos P_2O_5 per hectare, and potash as muriate at 50 kilos K_2O per hectare. The limestone and the first dressing of phosphate were applied before planting, while nitrogen, potash and phosphate have been applied annually, the latter being placed.

Growth records show that nitrogen has had the greatest effect in hastening growth, with no difference in fibre yields between single and double rates of nitrogen (1.18 and 1.19 tons fibre per hectare respectively). Single plots receiving double rates of nitrogen, lime, and phosphate have yielded 5–6 tons fibre per hectare during the first 3½ years of the trial, this being comparable with results formerly obtained on virgin land.

From field observations it was found that ground limestone has reduced the symptoms of chlorotic mottling almost proportionately to the dressings applied, and also improved the colour of the leaf. Phosphate has had a similar but less marked effect, and there are indications from sand culture work that phosphate produces broader leaves. Sisal lacking nitrogen is pale green, but sulphate of ammonia, whilst improving this chlorosis, is conducive to chlorotic mottling, especially if lime or phosphate is absent. When there is too much nitrogen, sisal leaves are apt to be long and flaccid and the fibre may be finer. Excess potash has resulted in acute chlorotic mottling even if lime and phosphate are present. This might be attributed to K replacing Ca in the clay particles with subsequent leaching of the calcium, or else that the greater absorption of potassium by the plant decreased the uptake of calcium and magnesium. There is a further possibility that chlorotic mottling is related to soil acidity and the uptake of minor elements to excess: other workers have reported excess cobalt in leaves showing chlorotic mottling. A deficiency disease known as "Purple Leaf-tip Roll" is noticeable in varying degrees in all plots but its cause is not yet clear. The symptoms tend to become milder with increasing amounts of lime, and to a much lesser extent with the double application of phosphate, but it is increased by nitrogen application and potash has no effect. Here, again, soil acidity may be a factor, since it is most prevalent on acid soils: the possibility of magnesium deficiency is under investigation.

Bulbil nursery manurial trials, which have been replanted annually on the same site, have shown consistently that 50 tons per hectare of either fresh or old sisal waste doubles or trebles the size of the plants with suitable spacing, and a greater effect still is obtained if the application is increased to 100 tons waste per hectare. Nitrogen alone, as sulphate of ammonia, induced chlorotic mottling, while phosphate had no effect.

Fresh sisal waste, applied in a field trial at 400 tons per hectare, is also showing a definite improvement in the growth of one-year-old sisal: the solid material extracted from 400 tons of leaf is also showing a similar effect. Liquid waste alone has not yet had much effect, nor has 50 tons per hectare of fresh waste applied along the rows as mulch, supplemented with nitrogen and phosphate.

While the information from fertilizer placement trials is not yet complete, current results show responses to nitrogen and phosphate, and indicate that it is advantageous to place phosphate in planting holes before planting and to apply nitrogen in the row in preference to broadcasting.

Ten fertilizer trials, sited on exhausted land on estates having different soil types, are not sufficiently advanced to supply much information, but foliar symptoms suggest that responses are not the same in all cases.

In addition to these experiments on direct manuring of sisal, indirect manuring is being investigated in field trials in which lime, nitrogen and phosphate have been applied to two-year leys of *Pennisetum purpureum* and *Panicum maximum*. The grasses are showing good responses to nitrogen and phosphate, and soil analyses, after ploughing in the grass, indicate that the pH increases almost proportionately to the quantity of limestone added, ten tons per hectare being sufficient to raise the pH from 5.6 to 7.0. On the other hand, heavy applications of sulphate of ammonia

* Kilos per hectare is roughly equivalent to lb. per acre.

reduced the soil pH to 4.7, and it is felt that alternative forms of nitrogen should be used on lime-deficient soils. Applications of phosphate improved the phosphate status of the soil, and it is hoped that excessive fixation has been avoided by this indirect method of application. Some of these trials have only recently been replanted with sisal and no results are available except to mention that the early growth has been satisfactory.

The correction of deficiency diseases is also under investigation, particularly banding disease, which is now common on many sisal estates in the Tanga Province and has been recorded from Kenya. It is primarily attributable to lack of potash. An experiment was started in 1947 on an estate where banding disease was rife, and striking results have been obtained. The soil is a dark brown clay-loam with a nearly neutral reaction. Responses to nitrogen and phosphate were not large enough to be significant. The increase in yield was entirely due to better and healthier leaves, since there was no difference in the number of leaves grown per plant in the healthy and diseased sisal. Fertilizer treatment of banding disease appears to be economic, and several sisal estates are now applying potash as a matter of routine.

Other trials suggest that applications of nitrogen accentuate symptoms of banding disease. It has been suggested that the soil K/N ratio is an important factor in controlling the potassium uptake by the plants and that K/N ratio of about 0.05 might be critical.

The most clear-cut practical conclusion to be drawn from these sisal manurial trials is that the rate of depletion of plant nutrients from the soil would be lessened if all waste effluent could be returned to the land. But the physical difficulties in transporting this bulky manure may be insuperable, owing to the very large areas involved, and it may well prove cheaper to use artificial fertilizers. There is no doubt, however, that sisal waste is valuable both as mulch and as manure, and it should be used more widely in bulbil nurseries. These are seldom extensive, and permanent sites could be chosen near the decorticating factory. Care is needed on land liable to be deficient in potash, since raising of the nitrogen status could result in the appearance of banding disease.

Nitrogen is clearly important for a vegetative crop like sisal, but sulphate of ammonia should not be used on acidic soils, since it appears to compete with the sisal for calcium. Both young and bearing sisal can be grown in association with grasses, and the nitrogen status of the soil could be enriched by means of grass leys between cycles of sisal, or by mulching with material cut from grass strips between the rows of sisal.

On certain soil types, phosphate may be useful in establishing young sisal, especially if used in conjunction with nitrogen. Sisal is a gross calcium feeder, and on the red earths continuous sisal-growing leads to progressive acidification of the soil. It is not yet known how far calcium affects the yield of fibre or its quality, but it has been observed that it improves leaf colour. Plants grown on soils low in calcium tend to be more susceptible to bole rot, but a definite association between these two factors has not yet been confirmed. Potash seems to be of importance only when banding disease is evident.

Before other recommendations can be made, much more experimental work is necessary, but at present it appears that the best returns are likely to be obtained when losses of crop through mineral deficiencies are such that applications of fertilizers give large responses.

The Relationships Between Phosphate Response and Base Saturation, pH, and Silica Content of Acid Soils

H. F. Birch, E.A.A.F.R.O.

The object of the work was to determine whether phosphate response in the field could be related to soil characteristics, with a view to using these in making subsequent fertilizer recommendations. The phosphate response data and the soil samples required for the investigation were supplied by the African Fertilizer Scheme and the Highlands Fertilizer Scheme and the crops tested were wheat, maize, millet, sorghum and grass.

It was at first assumed that phosphate responses would be most closely related to the amount of some form or forms of phosphate in the soil. Acid-soluble and adsorbed phosphate were accordingly measured by the method of Bray and Kurtz (1945), and, in addition, water-soluble phosphate, and "available" phosphate by Truog's method, were also determined. From these results it was concluded that there was no satisfactory relationship between phosphate response and

the amounts of acid-soluble or adsorbed phosphate in the soil, but a relationship was found between response and adsorbed phosphate when the latter was expressed as a percentage of the capacity of the soil to retain adsorbed phosphate. In general, the effectiveness of a given amount of adsorbed phosphate in supplying phosphate to the crop is inversely related to the adsorbed phosphate-fixing capacity of the soil with which it is associated.

Since these relationships were somewhat inconclusive, attention was directed to other soil data, and it was found that phosphate responses were significantly and inversely related to the percentage saturation of the base exchange capacity of the soil. It was also found that phosphate response was significantly and inversely related to the average yield of the untreated (control) plots, and this control yield was found in turn to be significantly and directly related to the percentage saturation of the base exchange capacity of the soil. For a given degree of base saturation a high control yield was usually associated with responses below those expected from the statistical calculation, and a low control yield usually gave responses exceeding those expected. By combining control yield and percentage base saturation in the calculation for expected phosphate response, a better relationship was obtained than by using either of these factors alone. One difficulty in this calculation is that the control yield may vary from season to season, and its practical implications require further study.

In the search for soil characteristics which could be related to phosphate response, reference was made to work by Nemec (1932) and McGeorge (1924) who had found that the contents of soluble iron and silica could give a measure of phosphate requirement. No relationship was found between iron and phosphate response, but the water-soluble silica and the silica which was extracted by 1 per cent citric acid gave a significant and inverse relationship with phosphate response. These two silica estimations are also significantly and directly related to the percentage saturation of the base-exchange capacity. It is suggested that the three determinations, pH, base saturation, and soluble silica may each be a well-defined characteristic of certain soil types. The high base saturated almost neutral soils of high silica content may be indicative of a montmorillinitic type of clay, and the lower base saturated soils of a kaolinitic type.

Any of the methods described, and particularly the percentage saturation of the base exchange capacity, can serve to indicate whether phosphate responses are likely, and the probable magnitude of these. A more accurate assessment of the latter is possible if something is known of the general fertility status of the soil as reflected in the control yields. Considering that soil productivity and fertilizer responses are a result of several factors such as soil depth, texture, slope, drainage, permeability of the profile, erosion, micro relief, climate, cultivation methods and chemical characteristics, it is surprising that phosphate response can be so significantly related to a single chemical soil characteristic.

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Fertilizer Response in Relation to Soil Type

G. H. Gethin Jones, E.A.A.F.R.O.

Responses of Wheat and Maize to Phosphate on Different Soil Types in the Kenya Highlands

P. Robinson, E.A.A.F.R.O.

These two papers are complementary, in that Robinson based his statistical treatments of responses on the soil types as defined by Gethin Jones, but this classification and mapping can only be approximate, because of the necessary variations within a soil type. Even following a detailed survey for the best possible site for representative plots, there are often appreciable differences in temporary soil fertility which cannot readily be observed but which are reflected in the vigour of growth. In the African settled areas there is the added difficulty that small units of land have been subjected to different cropping treatments over varying periods. The best that can be done is to select representative sites which have the greatest degree of apparent uniformity within an estimated mean fertility level.

In the Highland Fertilizer Scheme, the results of which are summarized by Holme and Sherwood elsewhere in this report, the soils of some 80 experimental sites were grouped into eight main types. The statistical analysis of the responses was based on these.

The relationship between the described soil types and phosphate responses showed that the variation *within* each of seven classified soils carrying wheat (Mean Standard Error of 1.68 bags per acre) is much smaller than the variation (Mean Standard Error of 4.91 bags per acre) *between* different soils. The relationship is not entirely due to similar intrinsic soils, as the breakdown into soil types tends to group together areas with similar climatic conditions with a similar incidence of disease and about the same time of planting, usually the same variety of wheat. These factors as well as the soil itself are accounted for in the responses and in the recommendations made.

The named soil types and their phosphate requirements are as follows:—

1. The *Kinangop* brownish-grey silt loam with seasonal impeded drainage contains 20 per cent to 30 per cent of a siliceous clay and 35 per cent to 45 per cent of silt with a poorly developed soil structure, below which there is a compact horizon with black and orange mottling and murram pellets: underneath this layer there is an impervious chocolate to greyish-black clay. Without added phosphate the yields of wheat are very low and uneconomic but there is a marked response to phosphatic fertilizers. On comparing dressings of 500 lb. per acre sodaphosphate with 160 lb. double superphosphate, statistical analysis indicates that, at present prices of fertilizers and of Grade I wheat, increases of 8½ bags of wheat per acre could be expected from the sodaphosphate, giving a profit of Sh. 367, whereas superphosphate should give an increase of 9½ bags with a profit of Sh. 419. These are expected responses computed from the data available from nine field trials, and they will, of course, be affected by seasonal variations of climate and local variations of soil: they cannot be treated as accurate forecasts.

2. The *Uplands* dark brown to orange-brown mellow loam is a leached soil with 40 per cent to 50 per cent of lateritic clay and 20 per cent to 30 per cent silt overlying a brownish-orange to orange-red heavier subsoil, locally with iron and manganese mottling, derived from tuff and trachytic tuff on slight slopes. This type includes two soil series, the one naturally well drained on the upper slightly steeper slopes, and the other with slightly impeded drainage at lower levels, but it would be difficult for farmers to separate them. On this soil, using 430 lb. sodaphosphate or 130 lb. double superphosphate per acre, it is expected that sodaphosphate should give an increase of 5½ bags of wheat per acre, with a profit of Sh. 218 while superphosphate should also give about 5½ bags per acre response, with Sh. 234 profit.

3. The *Njoro* dark brown loam is a comparatively young, little leached soil with 30 per cent to 35 per cent clay, over an orange-brown, gritty loam derived from black tuff and fine ash. It is rich in bases, with high amounts of magnesium and potash and also of soluble silica. The colour of the surface soil becomes a slightly orange-brown after prolonged cultivation, but it still contains a high amount of total soil nitrogen. Although yields of wheat have fallen following long cultivation, this soil gives no response to phosphates.

4. The *Rongai* reddish-brown to greyish-brown, gritty (ashy), coarse sandy loam to gritty, sandy clay-loam is similar to the Njoro type in being little leached, well supplied with bases, and with good values for exchangeable calcium, magnesium and potash and also for total nitrogen. It gives slightly better yields than the Njoro soil without phosphate, varying according to fertility levels, but it differs in that there is a fairly good response to added phosphates. There is also a small response with maize. Statistical analysis suggests that, with wheat, 350 lb. per acre of sodaphosphate should give an increase of over 3 bags per acre with a profit of Sh. 112, whereas 110 lb. double superphosphate should increase the yield by 3½ bags with a profit of Sh. 139. The profits with maize are rather lower, 180 lb. sodaphosphate giving 2½ bags per acre extra, with Sh. 67 profit, and 110 lb. double supers giving nearly 5 bags extra with Sh. 118 profit.

5. The *Kipkabus* brownish-red to red loam behaves as a friable loam, even although it contains 50 per cent to 70 per cent of a lateritic clay on dispersion; it overlies a dark red friable clay-loam. In the lower subsoil there are soft iron and manganese pellets, with more secondary manganese deposits near the weathering parent rock, a phonolite. This soil type has been highly leached and is low in all bases except magnesium. It shows a fairly good to good response to added phosphates, and with wheat it can be expected that 440 lb. sodaphosphate should increase the yield per acre by 5½ bags with Sh. 226 profit, while 120 lb. double super should give an increase of over 4 bags with Sh. 126 profit.

6. The *Plateau* orange-brown loam overlying murram is an easily recognized orange-brown loam over a gritty orange-red loam, with increasing amounts of iron and manganese concretions below the first foot, and with earthy laterite or "murram" about 3 ft. below the surface. It is moderately leached, with a fair amount of bases, but it is low in nitrogen. After long cultivation this soil type gives low yields of wheat and only a fair response to added phosphate. By adding 330 lb. sodaphosphate an increase of 2¾ bags of wheat per acre can be expected, with a profit of Sh. 96; by adding 100 lb. double supers roughly the same response and profit are likely.

7. The *Moiben* soil type is a reddish-brown, brown and grey-brown sandy loam to loam and contains at least three soil series but all have the common property of being derived from a mixture of lava and gneiss rock in varying proportions. All are naturally well drained, deep, resorted soils with weathering rock fragments of lava and gneiss and without any marked soil horizons or mottling. Their content of bases is fairly high, and they give good yields of wheat with only small responses to phosphate. By adding 260 lb. sodaphosphate an increase of about 1¾ bags of wheat per acre and a profit of Sh. 53 could be expected, whereas with 90 lb. double supers over 2 bags per acre and a profit of Sh. 73 is the estimated response. Smaller dressings of phosphate give some profit with maize, in that 80 lb. sodaphosphate will give an increase of nearly a bag an acre and Sh. 19 profit, while 70 lb. superphosphate should give 2 bags per acre more and Sh. 40 profit.

8. The *Kitale* reddish-brown to brownish-red, compacting coarse sandy loam to coarse sandy clay-loam is mainly derived *in situ* from gneiss rock with locally a shallow mantle of similar-looking locally resorted material. There is a great depth of a slightly heavier, uniform red loam to fine sandy clay-loam subsoil without any mottling. It differs from the lava-derived soil towards Endebess (*see* below) in that although it contains about 40 per cent coarse sand, it readily sets hard on drying out, when cultivation becomes difficult. The surface soil is high in bases. Wheat is not usually grown on this soil type. Maize gives some profit to added phosphate, 100 lb. sodaphosphate giving an additional bag per acre at a profit of about Sh. 23, while with 80 lb. double supers about 2¾ bags and a profit of Sh. 60 can be expected.

9. The *Endebess* red loam is a chocolate-red to red loam to fine sandy clay-loam, which overlies a great depth of dark red, friable clay-loam derived from Mount Elgon lava and tuff. It is high in bases, particularly in magnesium and potassium. It produces very good yields of wheat with a low response to phosphate.

The dressings given above were calculated as the mean theoretical dressings which would give the farmer the most profit on present prices. Because of differences in season, site, condition and management, the above calculated optimum dressings are only approximate. Dressings some 20 per cent to 40 per cent lower will probably be preferred by the farmer in most cases because of the smaller initial outlay, and less chance of a large loss if the crop fails due to poor rains. In addition this large reduction in application will result in only a small percentage drop in profit; a 20 per cent reduction gives only about 3 per cent less profit and a 40 per cent reduction only about 8 per cent less profit. Field recommendations are dealt with in greater detail by E. Bellis elsewhere in this report.

The African Fertilizer Scheme, which is described (by Doughty) elsewhere in this report was also examined and the soils of the experimental sites were classified as far as possible. Although ten main soil types were identified, including variants, there were many instances of too few representative experimental sites within a recognized soil type, and in consequence the number of soil types that could be usefully correlated with a sufficient number of completed experimental trials had to be reduced to six. There were not sufficient data to work out optimum dressings and only general observations can be made, based on the response of maize, sorghum and finger millets to the common dressing of 1 cwt. of triple supers per acre. In general terms, it can be stated that the pallid-coloured soils showed only small responses to phosphate, and that the need for this class of nutrient increases with the development of red and orange-red colours, first when this occurs in the subsoil, and that it is greatest when the whole soil profile is highly coloured. These latter more leached soils have good supplies of other plant nutrients, and, though they carry fair to good crops without phosphate, they give the greatest response to such applications. In these African Fertilizer Scheme trials there was a frequent response to a top-dressing of 1 cwt. per acre of sulphate of ammonia with both maize and

sorghum, whereas in the Highland Fertilizer Scheme trials the mean response was negligible. In this connexion it can be noted that the response to nitrogen in the African Fertilizer Scheme was greater in the pallid-coloured, more sandy soils where phosphates were less needed, and least with the more highly coloured soils where the response to phosphate was greatest. Intermediate soil conditions showed a fair response to both nutrients.

Fertilizer Responses in Relation to Soil Types. Field Recommendations

E. Bellis, Kenya Department of Agriculture

Robinson has demonstrated a considerable increase in precision which a simple soil classification makes possible in the predicting of the response of wheat in the Kenya Highlands to phosphate, though even within a soil type, the variability which he finds may be so great that even though on average the soil may show a good response to phosphate, the probability of obtaining poor responses can be quite high. Again, while Birch has established overall correlation between site data and the response of wheat to phosphate, these correlations become so much less clear when soil type is taken into consideration that a negative relation between response to phosphate and yield without phosphate on normally drained Kinangop loam becomes the only relation between recorded site data and phosphate effect which remains important: work outside the Highland Fertilizer Scheme has shown even the Kinangop loam relationship not to hold where drainage is poorer than normal. On the other hand, within a soil type, while site appears to operate through factors which find no general reflection in the Highland Fertilizer Scheme data, it is site which plays the dominant part in determining the response of wheat to phosphate, and while an overall assessment of fertilizer in respect of soil type provides a guidance which is essential to sound recommendations regarding the use of fertilizer on any given soil type, the Advisory Officer in making recommendations regarding a given piece of land will find it necessary frequently to modify, in the light of conditions prevailing on the site, any general recommendation which has been calculated for the soil concerned. In making such modification the soil data accumulated under the Highland Fertilizer Scheme will provide him with little guidance and he will necessarily have to fall back on his own knowledge and experience of the area, and of factors which are likely to have a bearing on fertilizer response there but which find no clear expression in the Highland Fertilizer Scheme data. He will also need to take into consideration the financial background of the farmer and the terms in which he will measure his returns.

As a general rule recommendations below the calculated optimum for the soil type will be given, as such recommendations can be made with greater confidence of being satisfactory than recommendations as great as or exceeding the calculated optimum. For normally drained Kinangop loam the following table gives a firm basis for recommendations for wheat:—

Yield without phosphate (bags/acre)	Recommended dressing (lb./acre)	
	Soda-phosphate	Double Super-phosphate
2½ bags/acre or less ..	500	160
For every bag per acre over 2½.	Reduce dressing by 56	Reduce dressing by 14

Based on a visual examination of the available data, the following recommendations have been made for fertilizing grass on certain important soils in the Kenya Highlands:—

Soil	Recommended Rate of Application (cwt./acre)			
	With the seed at sowing		As top dressing to established grass	
	Double Super-phosphate	Sulphate of Ammonia	Double Super-phosphate	Sulphate of Ammonia
Kinangop Loam	1½	1½	—	—
Upland Loam ..	1¼	1½	1¼	1½
Njoro Loam ..	1	1½	1	1½
Rongai Loam ..	1	1½	1	1
Kipkabus Loam	1¾	1½	1½	1¼
Plateau Loam ..	1½	1½	1½	1
Moiben Loam ..	1½	1½	1½	1¼
Kitale Sandy Loam ..	1	1½	1	1
Endebess Loam	1	1½	1	1

On established grass both the double superphosphate and the sulphate of ammonia should be applied early in the growing season while trial of further application of the sulphate of ammonia after each cut or grazing should be undertaken.

Nitrate Accumulation in Uganda Soils

W. R. Mills, Uganda Department of Agriculture

Some progress has been made in the study of nitrate accumulation at Kawanda since Griffith and Manning [1] and Griffith [2] published the findings of their preliminary investigations. The nitrate experiment at Kawanda has now been running for over three years. The later results have confirmed the original findings that high nitrate accumulation (up to 200 p.p.m. NO_3) may occur on bare fallow soil, very little (about 10 p.p.m.) on shaded and/or mulched soil and something in between on cropped soil.

The mass of data that has been obtained for this experiment has not yet been fully analysed and unfortunately it cannot be studied very critically since there was no replication. Trends in the fluctuation of the nitrate have been followed graphically and the results have emphasized the complex nature of the factors affecting the level of this nutrient. Some of the earlier results, which at the time appeared to be fairly conclusive, have not always been obtained in apparently similar conditions at a later date. One new point of interest has, however, emerged: the effect of nitrogenous fertilizers on nitrate status.

Addition of sulphate of ammonia causes the nitrate status of a soil to be raised both to a higher level and for longer duration than an equivalent dressing of nitrate of soda. This is due to the adsorption of ammonium ions by the soil colloids, thus protecting them from leaching. Farmyard manure behaves in a similar manner to sulphate of ammonia but without producing such high levels of soil nitrate. Other than immediately after application of sulphate of ammonia, the ammonium ion level in the soil is negligible. Limestone, although it reduces the soil acidity, does not cause an appreciable increase in soil nitrate content.

Clear-cut correlations of nitrate content and soil moisture, temperature and insolation cannot yet be made. It is believed that all three have an effect but of what relative magnitudes it is not possible to decide from the data available. Dr. Meiklejohn, who has scrutinized the graphs and laboratory data very carefully, believes that the connexion between nitrate accumulation and soil temperature may be closer than earlier suspected.

All the results over the three-year period were obtained for the 0–6-in. layer of soil. The distribution of nitrate within this layer at lower horizons has also been investigated. A summary of the findings of this work is given below:—

In the top inch a figure in excess of 300 p.p.m. of NO_3 may be obtained, with a sharp drop to 40–60 p.p.m. in the second inch which persists to about 9 in., when a gradual rise commences. It may well be that the major nitrification occurs in the surface inch of soil (future work may show that the process is confined to even shallower depths) or alternatively the accumulation in the surface may be simply due to upward movement of nitrate during the evaporation of soil moisture. These surface accumulations are most marked in the bare fallow plots but are found also on a lesser scale in both the shaded and the cropped plots. Under shade a typical result is 50 p.p.m. NO_3 in the top inch, dropping to 20 p.p.m. NO_3 in the second inch. In the cropped plots the differences are less. If the nitrification does occur in a shallow surface horizon it may be argued that rain washes the accumulated nitrate into the lower layers and there is, temporarily, a lower nitrate content in the surface soil with correspondingly more nitrate in the subsoil. Nitrate is then again produced in the drying surface and may possibly become "fixed". In the meantime the nitrate in the immediately lower horizons may become converted to other forms of nitrogen (denitrification) or may diffuse in soil moisture either up or down. Obviously there are many factors involved, of which shower frequency and intensity are but two. Nitrate contents in the top 6 in. in relation to soil moisture and rainfall thus present a different picture from that of the surface inch.

The effect of surface leaching was also found in samples taken every 6 in. to a depth of 6 ft. On bare fallow plots an accumulation of nitrate amounting to greater than 400 p.p.m. NO_3 at a depth of 3 ft. was found. The actual depths, where the peak accumulations occurred, were variable. Under shaded conditions the peaks tended to occur slightly lower. Under mulch there was a gradual increase to about 100–150 p.p.m. NO_3 at 6 ft. Possibly the peak (as related to increased leaching) occurred even lower in the profile. Under conditions of cropping the nitrate accumulations at depth were less than under bare fallow or shaded

conditions, yet a peak was still found, but it was lower down at 4–5 ft.

Much information on nitrate accumulation under various crops was also given by this nitrate experiment. Millet, maize, sunnhemp, all reduced the original content, the drop being marked particularly during the flowering of the crop. During the later life of the crops the level of nitrate remained very low. On the other hand, cotton, in early life, allowed a build-up of soil nitrate which dropped at the peak of flowering but later rose again. This is probably due to the longer insolation period of the soil carrying the cotton plants.

A most important discovery was made when the nitrate profiles from certain plots of the Kawanda Structure Experiment were examined. After three years' resting under a ley of elephant grass, chloris and paspalum, the nitrate content of the whole profile down to 6 ft. was found to be almost nothing. After opening up the ley, the rate at which nitrate accumulation occurred in the surface horizons varied with the species of grass; paspalum very slowly with low NO_3 for a long time; elephant grass more rapidly to a higher NO_3 figure; chloris was intermediate.

The effect of three years' monoculture of other crops (part of the Structure Experiment) on nitrate status was also studied. Results are, as yet, insufficient to be conclusive, but it does appear that in the tropics, as in temperate regions, a legume has a beneficial effect on nitrate accumulation. *Leucaena glauca* and *Pueraria phaseoloides* are two which have given enhanced NO_3 in the surface after clearing, although at depth, NO_3 content is low. Annual crops in general promoted accumulations at depth with variable nitrifying ability in surface soil.

It is intended to carry on shallow and deep profile studies of nitrate accumulation over the next few years, both at Kawanda and other localities with a different climate. Nitrate and its relation to nitrite, total nitrogen and C/N ratios will also be investigated concurrently with microbiological studies by the staff of E.A.A.F.R.O. Dr. Meiklejohn has already begun the study of microbiological aspects of the problem.

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The Microbiological Aspects of Soil Nitrification

(With special reference to the Kawanda Experiment on Nitrate Accumulation)

Jane Meiklejohn, E.A.A.F.R.O.

Nitrification is the formation of nitrates, in the soil, in sewage, or in manure heaps and similar places, by oxidation. The starting point of the oxidation is normally ammonia, and in soil the ammonia is derived from the breakdown of organic matter present in, or added to, the soil. If an ammonium salt such as ammonium sulphate is added as a fertilizer it is quickly nitrified in any normal soil.

It was shown nearly 80 years ago that nitrification in sewage is a biological process, and that the same was true of soil; about 60 years ago the bacteria which carry out the process were isolated. These, the only organisms which are definitely known to produce nitrate by oxidation, are bacteria of a very peculiar type; they are autotrophic, that is to say, they are independent of organic matter, both as a source of carbon and as a source of energy. Their only source of energy is the oxidation reaction they carry out. There are two distinct types of these bacteria, one type oxidizing ammonia to nitrite, and the other oxidizing nitrite to nitrate. Both organisms are almost invariably present together, as is shown by the fact that accumulation of nitrite in a soil is very rare, and the normal amount of nitrite in soil is a fraction of one part per million. Both kinds of nitrifiers are usually supposed to be favoured by slightly alkaline conditions, and are known to grow better in the dark than in the light.

From a microbiological point of view, the results of the Kawanda nitrate experiment are quite unexpected; here there is a much greater accumulation of nitrate in unshaded bare fallow than in shaded, or mulched, plots; the accumulation takes place during the drier part of the year, and the maximum nitrate content of the soil in all uncropped plots was greater in 1949–50 than in 1950–51, the first year being both warmer and drier than the second. It should also be mentioned that the surface pH of the soil was about 5, and that the addition of limestone, while it altered the surface pH to 7, made no difference to the rate at which nitrate accumulated.

In the absence of any microbiological data, if an attempt had been made to explain these results in terms of the microbiological pro-

cesses most likely to operate, it might have been supposed that the soils contained nitrifying bacteria with a high temperature optimum (40° C. or even higher), and with a wide range of pH tolerance. Or, alternatively, it might be supposed that there was a smaller loss of nitrate, rather than a greater formation of it, on the unshaded plots; this could happen if the nitrifying bacteria were more resistant to heat and drought than the denitrifiers, or the micro-organisms which consume nitrogen.

Now it can be said straight away that the soils from the Kawanda experiment do contain nitrifying bacteria of the classical autotrophic types; cultures have been obtained, on liquid media free of organic matter, in which ammonia is oxidized to nitrite, and nitrite to nitrate. The bacteria in these cultures adhere to solid particles, and form the characteristic tiny colonies when plated on ammonium sulphate agar or nitrite agar.

But the results of microbiological tests carried out in the laboratory do not agree with, and do not explain, the results obtained in the field. Enrichment cultures were made by inoculating liquid media with soil from different plots; they were incubated and tested at intervals for nitrite.

On the whole, cultures made from the soil of the shaded and the mulched plots produced more nitrite from ammonia than did cultures from the unshaded plots, where nitrification in the field had been more vigorous. The same kind of result was seen with cultures on nitrite medium from the same set of soils (here the disappearance of nitrite is an indication of oxidation). Again, nitrite disappeared much faster from the cultures made from the soils of the shaded or the mulched plots; a strong positive test for nitrate was always obtained in cultures where the nitrite had all disappeared, showing that the nitrite had been oxidized. Not only is it true to say that these results contradict the results of the field experiment, the supposition, based on the results obtained in the field, that the nitrifying bacteria in these soils would have a high optimum temperature and a wide pH tolerance, is not confirmed by laboratory tests, but the contrary is found.

There seems to me to be three possible explanations for the fact that these laboratory tests do not agree with the results of the field experiment: in the first place, it is possible that these soils contain nitrifying bacteria which will not grow under the cultural conditions I have tried; this possibility is being investigated, and it is proposed to use various solid media to see if other types of nitrifiers will grow on them.

In the second place, there is the possibility that the nitrifying population of these soils has radically changed since the experiment was begun; it must be remembered that the greatest accumulations of nitrate were found in the first season of the experiment, late in 1949 and early in 1950, and that the last manurial treatments were applied in April, 1950, and have not been repeated since.

Thirdly, there is the very interesting possibility that the process of nitrification in these soils is not biological. Very little is known about nitrification in tropical soils, but about 20 years ago, Dhar, working in India, put forward the hypothesis that a photo-chemical reaction, catalysed by various metallic oxides, was the only mechanism which could explain nitrification in tropical soils in the dry season. This hypothesis was not supported by any very good evidence; it was based on a few experiments done with simple solutions exposed in beakers to the sun, in which there were no precautions taken against contamination; however, the fact that the evidence for a hypothesis is insufficient does not necessarily mean that the hypothesis is not true. In the case of the Kawanda experiment, the following circumstantial evidence can be quoted in support of the hypothesis that a photo-chemical reaction can account for the observed accumulation of nitrate: the greatest accumulations of nitrate took place in bare soil exposed to the sun; nearly all the nitrate formation was in the top inch of soil; the surface soil is very hot (temperature at 2 in. below the surface rose to 43°, and at the surface may have risen to 60° or more), and very dry; these soils have a very high content of exchangeable manganese.

However, the question whether nitrate accumulation in these soils was biological or photo-chemical in character cannot be settled by any more work done on this same experiment; what is needed is an entirely new experiment, or set of experiments, in which chemical and microbiological studies can be made simultaneously right from the start.

From the agricultural point of view, the most important aspect of nitrification is what happens to the nitrate after it is formed. There are four possibilities: (1) the nitrate may remain unchanged in the topsoil until it is washed down to the subsoil by rain; (2) it may be

taken up by plant roots; (3) it may be used as a source of nitrogen for growth by ordinary heterotrophic bacteria and by fungi; in this case the nitrogen is locked up in fairly insoluble cell constituents; (4) the nitrate may be reduced to nitrogen gas by denitrifying bacteria, and so be lost from the soil into the atmosphere.

Considering what happens to the nitrate formed in the plots at Kawanda, it is probable that (1) is the only process taking place in the uncropped plots, as the accumulation of nitrate at a depth of 4 to 6 ft. is so great as to make it unlikely that much has been removed by processes (3) and (4); however, if process (4) does not operate, it is not because denitrifying bacteria are absent from the soil; denitrifiers of two different types were easily isolated from the soils of the ten uncropped plots studied. In the cropped plots, nitrate must, of course, be removed by process (2); but here, again, there is so much nitrate in the subsoil as to make it unlikely that much is removed by processes (3) and (4). That is to say, the actual loss of nitrogen due to nitrification in these soils is not great; but leaching removes it out of reach of shallow-rooted plants.

The Nutrition of Maize and Sorghum in Sand Culture

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By growing plants in pure sand which holds no nutrients it is possible to feed to them precise amounts of nitrogen, phosphorus, potassium and so forth. In this manner it is possible to measure with some precision how the plant behaves when the level of supply of any one nutrient is altered in relation to the level of supply of the others.

In the sand culture experiments with maize and sorghum all the major and minor nutrients were supplied at fixed adequate levels except nitrogen, phosphorus and potassium. These three were each supplied at three different levels, low, medium and high, so that the effect of, say, low nitrogen with high phosphorus and medium potassium among the other combinations could be measured. The object of this work was to try and explain the results of some field experiments.

While experiments of the above type were being conducted the opportunity was taken to measure the consumption of each of the two major elements, nitrogen and phosphorus, throughout the whole period of growth from seedling to maturity and at all the different combinations of supply levels.

The consumption of phosphorus by the plants was found to depend only on the level of supply. If it was supplied in very dilute solution only a small amount was taken up even though the total amount of phosphorus available in the solution was more than the plant required. Further, as the concentration of the phosphorus in the solution was increased, progressively larger amounts were consumed. In other words, of two solutions each containing the same total amount of phosphorus, the one which is most concentrated is the one which is the better supplier of phosphorus to the plant. This result was found not to be affected by change in level of the nitrogen supply. Even if the nitrogen supply was so low as to limit growth the stunted plants consumed phosphorus at the same rate as better-nourished plants.

The nitrogen uptake, however, was found to be linked with the phosphorus supply. The plant apparently takes up little more nitrogen than it can reasonably use so that high nitrogen consumption is to a large extent associated with high phosphorus consumption.

In both cases neither the nitrogen nor phosphorus consumption was affected by the particular levels of potassium used in the experiments. The main effect of potassium seemed to be in increasing the water held by the tissues of the young plants. With high potassium supplies they were more sappy.

Both nitrogen and phosphorus are consumed in ever-increasing amounts as the plant grows in size until the flowering stage is reached. Thereafter the consumption of nitrogen falls off rapidly but the phosphorus uptake continues at a high level through flowering and the development of grain.

The growth studies showed that the interaction between nitrogen and phosphorus was most marked. They had to be supplied in suitable amounts to balance one another otherwise growth was inefficient. For example, if nitrogen limited growth no amount of additional phosphorus would make the plant grow any larger; likewise, if phosphorus limited growth no amount of additional nitrogen would make it grow any larger. The state of balance between nitrogen and phosphorus can be established at many different levels of

supply but of course only the highest suitable level of balance produces the largest plant. Both nitrogen and phosphorus affected the earliness of maturation. If the levels were high the grain matured much earlier than if the levels were low.

Although the plants which received the highest level of nitrogen and phosphorus supplies gave the earliest and highest yields it was possible to show that during the slower maturation of slightly less well-nourished plants, by reason of a longer period of uptake of nitrogen, they can attain yields nearly as high as those of the well-nourished plants.

It would seem, therefore, that although perfectly balanced nutrition at a high level is an ideal state, slightly unbalanced nutrition at a similar high level is likely to give nearly as efficient grain production though associated with delayed maturity and less uniform ripening of grain.

It would be unwise to generalize too much from experiments where the plants are kept under the best possible conditions of water and food supplies. However, there can be no doubt that the balance of nitrogen and phosphorus supplies at adequate levels is very important in obtaining the highest yields. It is, of course, impossible to suggest the most suitable application of fertilizers to attain this result, for soil, water, climate and disease will all play their part. However, with this in mind, the interpretation of some field experiments should be easier.

The uptake experiments suggest that it is important to apply phosphorus fertilizers at an early stage, because the plants can grow quickly when they take in adequate amounts of phosphorus from high concentrations in the soil solution. They also suggest that nitrogen fertilizers can be applied at any reasonable time before the period of peak demand just before flowering and that if early rain is likely to carry nitrogen below the root zone of the plant a few weeks' delay in application may have no serious effect on final yield.

BOOK REVIEW

THE GENETICS OF THE DOG, by Marca Burns. Technical Communication No. 9 of the Commonwealth Bureau of Animal Breeding and Genetics, Edinburgh. Commonwealth Agricultural Bureaux, price 12/6*d*.

The author is both a geneticist and a dog breeder. She has succeeded in the difficult task of presenting a book which is both an up-to-date reference volume for the scientific worker and an eminently readable one for the practical dog breeder. There are chapters on Mendelian theory, reproduction, conformation, physiological peculiarities, abnormalities and disease, behaviour, coat, skin and colour, the use of genetic formulæ in colour breeding and successful breeding systems. The interests of the British and Commonwealth dog-breeding fraternity have been particularly considered and the book should prove of great interest and value to the many dog breeders in East Africa.

J.A.